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ENERGY CONSERVATION IN THE FOUNDRY INDUSTRY

A compilation of papers presented at a seminar sponsored by CANMET and the Ontario Chapter of the AFS in Cambridge, Ontario, October 30 and 31 1980.

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"The opinions expressed in this report are those of the individual authors and not necessarily those of the Department of Energy Mines and Resources".

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TABLE OF CONTENTS

		Page
Foreword	W.H. Erickson, Director, PMRL, CANMET, EMR Canada, Ottawa	ii
Energy Requirements in the Foundry	R.K. Buhr, CANMET	1
Heat Recovery	B.W. Robinson Ontario Hydro	9
The Energy Situation	R. Hislop Consumer's Gas	33
Energy Conservation, The Viable Alternative	W. Chic, Ontario Ministry of Energy	46
Energy Use in the Canadian Foundry Industry	B. James, C.R.E.B. EMR Canada	53
Efficient Ladle Preheating	K.G. Davis, CANMET	71
How to Increase Cupola Efficiency	R.D. Warda, CANMET	86
A Review of Foundry Energy Conservation at GM of Canada	D. Braithwaite GM of Canada	112
Energy Conservation in Canron's Ferrous Foundries	J.C. Hungate Canron Ltd.	120

ENERGY CONSERVATION IN THE FOUNDRY INDUSTRY

FOREWORD

The production of castings requires the consumption of considerable quantities of energy. The rapid increase in the price of all forms of energy has therefore had a very large impact on the foundry industry. In the past, the industry has concerned itself with various means by which production could be increased and if additional energy was needed, it mattered little. Today, each and every modification, change or new technology introduced has to be evaluated regarding the energy consumption associated with it. Energy cost, more often than not, is a decisive factor in selecting the process to be employed. Thus, the more efficient use of available energy and /or its conservation is of major importance to each and every foundryman.

It is also important to review older ideas which may be of interest today, but which were discarded previously because of the reduced influence of energy utilization in our thinking. Efficiency in heating of make-up air was never a major concern in the past, but today with oil prices around $1.00/gal, that old thinking has to be discarded. It now makes sense to introduce more sophisticated air recirculation systems, to use close-capture fume hoods, etc. Every aspect of the foundry operation must be closely examined to determine the energy saving potential available.

This seminar was planned, with the cooperation of the Ontario Chapter of the American Foundrymen's Society, to bring together a number of speakers from industry and government and to present a range of information and ideas on energy conservation. We have been fortunate in the response, and our gratitude to all speakers who participated is acknowledged. Speakers were asked to orient the presentations to the needs of the operating foundryman to enable immediate and direct use of the information and ideas in operations. We believe they have succeeded in this. The data should be applicable to both small and large foundries alike.

All presentations are not reprinted here as some talks were based on informal notes only. Those presented here do give, we believe, many thought provoking ideas which should be of considerable interest to all foundrymen.

W.H. Erickson, Director, PMRL

PHYSICAL METALLURGY RESEARCH LABORATORIES
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ENERGY REQUIREMENTS IN THE FOUNDRY

by

R.K. Buhr

INTRODUCTION

I would like to take this opportunity to welcome you to this seminar. I hope it will be the first of many. I would also like to thank the Ontario Chapter of the AFS for their suggestion to hold this seminar in Cambridge and for their offer to co-sponsor the event. I hope, also, that this will mark the beginning of many such undertakings.

We are very fortunate to have a distinguished list of speakers who will be telling you how to conserve energy in the foundry. I would like to thank them publicly for the time and effort they have put into this seminar and for their willingness to participate in the topic. I know that all attending will leave with new ideas on how to improve the energy useage in their plant.

During the next few minutes I would like to present you with a few figures dealing with the energy requirements a foundry needs to produce a casting. I will also try to explain, from an energy point of view, the trend towards lighter weight metals in the transportation area. A brief analysis of the energy distribution in the production of castings will be used to demonstrate areas where research has the greatest potential, and this will be supported by giving some examples of the areas where we have completed or are currently involved in research.

It is worth repeating that energy is money. As the price of all forms of energy continues to increase, this fact becomes more and more evident. It was only a few years ago that the cost of energy was of secondary importance and taken for granted. I wonder how many people could have predicted the current price of energy back in 1970. For that matter, if such a

prophet existed, how many people would have listened? Similarly, it is difficult to predict the events of 1990 and what the energy situation will be then. All that can be said is that energy problems, both as to price and availability, will increase in severity, and so it is reasonable for us to continue to be concerned with this problem; it will not go away.

All foundry operators are concerned with the production of fully saleable castings at the least cost. In an effort to achieve this objective he must control the large number of variables involved. The quality and price of raw materials purchased must be monitored very closely. There are many cases where problems can be directly related to the raw materials purchased. Next, the various processes involved in the production of the castings must be monitored and controlled. These include sand and core preparation and distribution, the moulding operation, melting and pouring, cleaning and heat-treatment, external pollution abatement equipment, internal environment, including air replacement, noise abatement, health and safety of the workers. In each and every aspect there is a significant energy component. Management, control and conservation of this energy component can, therefore, be a most important factor in permitting the foundry operator to achieve the goal of a saleable casting at a minimum cost.

To illustrate these comments, let us look at the energy requirements needed to produce a ton of saleable gray iron castings using a cupola for melting, according to the US Bureau of Mines, see Fig. 1.

The wide range of items identified indicate the complexity of the operation as well as the problems associated with detailing an energy picture of the process. Regardless, it does show areas where energy usage is greatest and consequently, where savings might most readily be made. The distribution of the energy in the general categories cited, based on this figure, are shown in Table 1.

As one might anticipate, melting consumes the most energy, followed by moulding and coremaking and space heating. Casting, shake-out and cleaning consume about the same amount of energy as pollution control.

I do not have a similar breakdown of the energy for the production of castings in other metals. It should not be excessively different for steel or copper-base alloys, e.g., an article from France indicated that it requires about 40×10^6 Btu/ton for steel castings. For aluminum and

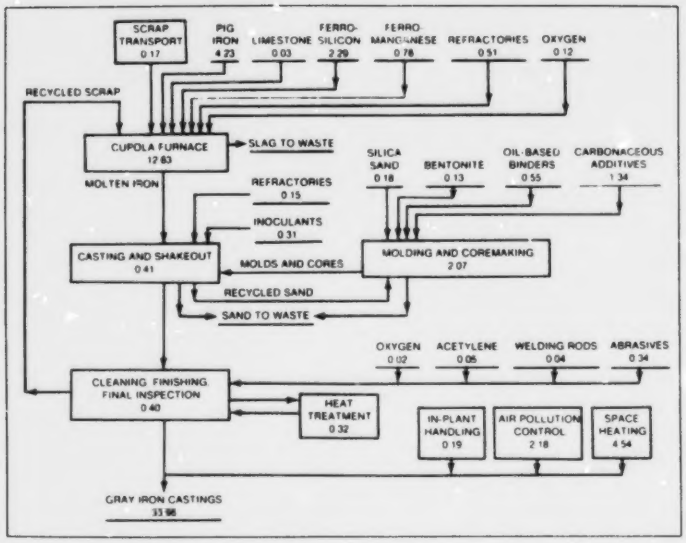


Fig. 1 - Energy requirements for the production of a ton of Gray cast-iron castings. Units quoted are BTU x 10^6. (neg 3761)

Table 1 - Distribution of energy in the production of gray iron castings

Operation	Energy distribution, %
Melting	61
Moulding and coremaking	13
Space heating	13
Pollution control	6
Casting, shake-out, cleaning	6
Other	1

magnesium castings the energy needs in melting are different, and are dependent on the amount of returns involved in the melt.

As you are aware, considerable amounts of electrical energy are needed to produce aluminum ingot. Even greater quantities of energy are needed to produce magnesium. However, the amount of energy needed to remelt either of these metals is quite small, as shown in Table 2.

Table 2 - Energy requirements and savings recycled vs virgin material use

	Virgin material Btu x 10^6/ton	Recycled material Btu x 10^6/ton	Recycled: Virgin ratio
Aluminum	175	6.8	3.9
Copper	46	5.9	12.8
Iron	14.6	5.7	39.0
Magnesium	310	6.4	2.0
Titanium	430	179	41.6

It requires only about 4% of the original energy input to remelt aluminum and only 2% in the case of magnesium. In general, iron castings are being replaced with an equivalent volume of aluminum in the automotive industry. When this factor is considered for 100% remelt the energy needs for aluminum castings, compared to gray iron castings, are close to being the same. Since, however, it is impractical to consider a 100% remelt situation, the relative energy requirements for virgin, 50:50 charge, a 70:30 mix and 100% recycle are shown in Table 3.

Table 3 - Energy needs for different virgin: recycle mixes (volume basis)

Metal	Density g/cc	Energy required for mixes (Btu x 10^6/ton)			
		Virgin	50:50	70:30	100% recycle
Aluminum	2.7	66.0	34.3	21.6	6.8
Magnesium	1.8	78.1	39.8	24.5	6.2
Cast iron	7.15	14.6	10.15	8.36	5.7
Copper	8.7	56.1	31.6	21.84	5.9

In the case of automotive parts, it is stated that 1 lb of Al will replace 2.1 lb cast iron and 1 lb of magnesium will replace 3.9 lb of cast iron. The gas saving potential in such a weight saving is reported to be 7.6×10^{-6} gal/mile. If the energy content of a gallon of gasoline is

150,700 Btu, a car being driven 12,500 miles per year would make up the difference in energy expended due to using aluminum castings (70:30 mix) in about 6 months. In the cast of magnesium castings, the time to repay the energy cost would be about 1 1/2 years in the case of a virgin melt, but only 6 months if a 50:50 mix were available.

These figures are largely based on the premise that the parts being replaced have adequate strength on approximately a one for one volume basis. This may or may not be the case. If we examine the energy requirements on a required mechanical property basis, the situation could be altered, as demonstrated in Table 4.

Table 4 - Energy requirements related to material properties

Material	Tensile strength ksi	Fatigue strength ksi	Total energy (kWh) per ksi of Tensile str.		Total energy (kWh) per ksi of Fatigue str.	
			Virgin	70:30	Virgin	70:30
Aluminum	30	10	2.2	0.72	6.6	2.16
Magnesium	30	15	2.23	0.70	5.21	1.63
Cast iron	30	10	0.5	0.34	1.46	1.0
Copper	40	15	1.4	0.55	3.74	1.46

Using this as a basis, cast iron is the least energy intensive alloy per unit of tensile or fatigue strength. I would repeat, however, for the transportation applications, the savings experienced in fuel economy should be considered.

AREAS FOR RESEARCH

Where are the areas where research should have the most benefit from an energy point of view? In reviewing the information presented, it is obvious the greatest expenditure of energy occurs in the melting process. Thus, anything that can be done to reduce this should be of considerable benefit to the industry. Currently, we have been measuring the efficiency of operation of a large number of cupolas in Canada, (see presentation by Dr. Warda in this

report) and of the methods available to improve the efficiency of operation of these furnaces.

The melting of steel in the electric arc furnace or in induction furnaces can be made more efficient by the use of natural gas burners to reduce the melting time. Reduced turn-around time in melts is another way to reduce energy consumption in melting furnaces; have the next charge ready for immediate introduction. Proper design of gas-fired furnaces can be beneficial - just the use of proper covers over the melt can save considerable energy.

An area of concern especially to Canadian foundrymen is that of space heating. I'm sure you will be hearing from different speakers on this topic, and of the methods available to use the waste heat in foundries. I have shown the breakdown of the energy needed to produce cast iron castings using a cupola. An interesting exercise is to determine where the heat produced from the combustion of the coke is divided. Table 5 illustrates such a distribution.

Table 5 - Distribution of energy from cupola coke

In melted iron	40%
Latent heat in stack gases	35
Sensible heat in stack gas	13
Other, slag, losses, etc.	12

Approximately half of the total energy available is going up the stack. Interestingly, this particular cupola is running at a 40% efficiency. Dr. Warda will be showing that this is higher than normal. Thus, for many cupolas, the amount of energy going up the stack may be higher than this figure. Recently an energy audit was made in England for cast iron foundries. Amongst a number of recommendations in that report was one which advocated the use of recuperative hot blast for all cupolas which were run for any significant amount of time. The reason for this was to better utilize this heat wasted in the stack by both preheating the blast air and for inplant heating purposes. An area where more research is needed, however, is in the

design of suitable heat exchangers. Attempts to recover the heat from these offgases are often troublesome as they are not clean, and can plug heat-exchanger tubing reducing their efficiency to unacceptable low values.

In the area of moulding and coremaking, of growing concern is the increasing cost of petroleum-based organic no-bake binders. The OPEC control over oil prices and its far reaching effects have resulted in these binder costs escalating at an ever increasing rate. The alternatives are the inorganic binders based on the sodium silicate system, with their inherent high-hot strength and poor shake-out characteristics, as well as difficult reclaimability. Research is needed to develop a sand binder system having the desireable characteristics of the two types and none of the disadvantages, i.e., controlled setting, readily available non-petroleum based binders, non-toxic and odorless, good shake-out and easy reclaimability. We are currently working on such a system, not expecting to meet all the requirements, but hopefully to find a reasonable alternative. We are now carrying out some commercial trials with such a binder to determine its acceptability and feasibility before pursuing the development further. Regardless of the results, we believe this to be an area of considerable interest to all foundry operators.

Pollution control is not a topic one normally mentions in the same breath as energy conservation. Certainly, there appears to be inconsistency in the various government departments, one insisting on abatement controls requiring the expenditure of considerable energy, and another advocating ways and means for energy conservation. One such problem with most pollution abatement devices is that the hot gases to be cleaned must be cooled considerably before treatment. We have developed a pollution abatement device which can treat these gases without cooling. This is called a packed bed filter, and I have talked of this to many of you present and will not repeat it now. The only point is that the gases are cleaned and still hot, thus reducing the heat-exchange problems just mentioned.

Preheating of ladles can consume considerable energy in the form of gaseous fuels. There are a number of foundries who simply put the torch in a ladle and let it go until the time it is needed. The waste of energy can be quite high. We have been trying to quantify the preheating needs in Ottawa, and Dr. Davis discusses this work in his paper included in this report.

Finally, I would like to talk about an area for energy conservation which few foundrymen consider from an energy saving point of view. I have shown that the main consumer of energy in the foundry is the melting operation, and anything that can be done to reduce this energy consumption is very beneficial. One such method is to increase the yield. At 50% yield, it requires 2 tons of metal to be melted to produce 1 ton of castings. A significant savings in energy can be realized if that yield could be increased to say 60%.

Increasing yield can be accomplished by three methods. The first is to reduce the gating and risering requirements and the second is to reduce scrap. Either method requires improved quality control and improved technical assistance. Hiring of properly trained personnel is an excellent investment which should pay for itself in a very short time. Smaller foundries seldom exploit this route, and leave themselves operating in a generally inefficient manner.

The third method, is to convert to one form or another of permanent mould casting wherever possible. The yield from these processes are usually much better than can be obtained in sand casting, e.g., in low-pressure-casting yields as high as 95% have been reported, representing a very significant reduction in energy requirements. We have just started a project in Ottawa in this area. We will be learning the current technology via the production of aluminum castings, and then we plan to expand this technology into the production of castings made in higher-melting-point alloys such as copper- and iron-base alloys.

In conclusion, I would like to leave you with this thought. We are, and will continue to be faced with conserving energy if we are to survive. Let's look at it as a challenge to improve the technological capabilities of our industry, to upgrade our quality and improve our competitive position, both domestically and in the export market. This is the aim we have at the Physical Metallurgy Research Laboratories, and we hope that you will continue to help us by informing us of your long range problems and cooperate with us in performing inplant tests to prove out any developments we might make.

HEAT RECOVERY

by

B.W. Robinson

Many industrial plants generate and discard enough heat in their various processes that if it were recovered and re-used they could completely eliminate the need for space-heating fuels.

Prior to 1973, engineers suggesting installations that would do this had to fight the economics of cheap energy. In four short years, however, the picture has changed completely. Energy costs are high and going higher and some plants have had their first taste of shutdowns for lack of fuel.

Basic metal industries, like foundries, forge shops, heat treaters, steel mills, etc. should not have to spend much for space heating. There is more than enough energy in their Btu-rich exhausts to do the job. Heat-exchange and heat-storage technology is so advanced that many plants should be able to completely eliminate the use of fuel for space heating.

A program like this begins with a survey of available Btu. The first step is to get temperature readings as follows:

1. From every vent or stack on every fuel or energy consuming operation in the plant. Includes: stacks on hoods, dryers, furnaces, ovens, heated tanks and so forth.
2. From fluids used in coolant lines for furnaces, air-compressors, condensers, heat-treat-quenching etc.
3. Floor and ceiling temperatures in each department of the plant.

The second step would be to know what and how many contaminants are contained in these exhausts.

Even low-temperature readings of a few degrees above ambient may be significant if the volume of the exhaust is great.

You will find exhausts carrying from 5000 to 5,000,000 Btu or more and we hope you will wonder why you are throwing all this energy away and how long you think you can continue to do so.

A major source of waste energy are the hot products of combustion discarded by most fuel burning industrial processes. These hot combustion products typically contain anywhere from 40% to 90% of the energy initially

put into the process. This is particularly high where high-excess air-firing ratios are used.

It makes a great deal of sense to recovery as much as 80% of this wasted heat and re-use it in the combustion process to reduce fuel consumption by 25% or more.

Handling high-exhaust temperature is always difficult as they produce a huge temperature difference across any heat-recovery device. This results in unequal expansion rates, warping of castings, destruction of seals and metal fatigue. Ceramic materials can handle temperatures of 1500°F but because they have a negative coefficient of expansion, it is difficult to attach them to a steel shaft which has a high positive coefficient.

There are ways of putting that energy to work heating the plant. The three most popular are air-to-air heat recovery, fluid-to-fluid (or air) recovery systems and direct air recirculation. The last one is most important because environmental requirements to clean up exhausts means you are likely exhausting very clean air. Why not recirculate it back through the plant's heating system. At any rate, once you have all this information you are in a position to discuss the direction you should go with your engineers and equipment suppliers.

There are two types of air-to-air exchangers; regenerative and recuperative.

Regenerative units alternate hot and cold airflow over heat transfer surfaces, thus transferring Btu from one air stream to the other. They are usually stationary and have a high efficiency because of the length of time the gas is in contact with the heat-exchange medium.

Recuperative units maintain continuous hot and cold air streams across heat-transfer surfaces divided by a barrier. Heat is transferred from one air stream to the other by conduction through metal plates; temporarily stores in porous materials such as wire mesh as in heat wheels; or by fluids as in the case of heat pipes or run-around systems.

A review of heat exchangers should cover the limitations the environment will impose. Processes almost always generate exhaust streams laden with aerosols, gases, vapours and particulates. Gases are associated with combustion - generated exhausts. Vapours and aerosols come from evaporation or polymerization of chemicals. Particulates can be solid or liquid. To these we can add fumes and smoke as general terms. All have one common

characteristic that affects heat exchangers: they deposit coatings on anything they touch. These coatings, or deposits, drastically reduce heat exchanger efficiency. And, this factor, more than anything else, should govern the choice of heat exchanger selected for an application.

The regenerative exchanger, for example, should not be used where exhaust streams are laden with gases, vapours and particulates. These pollutants will quickly coat the types of heat transfer media with which regenerative types are constructed. This occurs through the condensation mechanism that is actuated by the temperature drop the exchanger induces in the exhaust stream.

Recuperative heat exchangers also, suffer from this same problem, but are usually easier to clean, in fact they can be made to be self-cleaning.

All heat exchangers should be operated in such a way as to prevent condensation of any material going through them, unless they are especially designed to take advantage of the latent heat which nearly all vapours possess.

Yet another important factor is known as cross-contamination, which refers to contaminants in the exhaust stream being carried or leaked over into the incoming stream. This is difficult to control with regenerative exchangers, but relatively easy with recuperative exchangers, as many of them employ complete separation of the two air streams. Also, liquid exchangers have no cross-contamination problem.

The efficiency of any heat exchanger depends on a number of factors and approaches 100% where two streams equal in volume and velocity remain in contact long enough. Obviously, this is impractical, so equipment manufacturers design them only for optimum efficiency. Usually the higher the temperature difference between the hot stream and the cold stream, the greater is the efficiency. Therefore, where high temperature exhausts are involved, efficiencies of at least 80% are to be expected.

A further consideration of comparing efficiencies of different exchangers is the air velocity and pressure drop across the unit. An increase in static pressure will increase fan horse-power requirements considerably, which is no way to boost efficiency.

This brings up the fact that all heat exchangers must be kept clean in order to minimize static pressure differences and to avoid decreasing the rate of heat transfer. Some exchangers allow particles up to certain sizes

to pass right through. These will not cause trouble, but others need filtering in order to protect the exchanger.

The location of fans needs careful consideration. It is good engineering practice to arrange to have a higher pressure on the fresh air intake side than on the exhaust side, so that any leakage of contaminants will not enter the intake. Of course, the intake should be located some distance from the exhaust for the same reason.

Before looking at some of the various types of heat exchangers, a final consideration must be to control the rate of heat recovery to match the needs of the plant. The total amount of heat which can be recovered may not be needed and indeed heat may not be needed at all at various times of the year. Simple by-pass ducts and louvres controlled by thermostats are most often used with air systems, and throttling valves with liquid systems.

Differential pressure switches are needed to inform us when filters need changing or that the device is plugged. And finally, it is good practice to provide some indicator that the device is still operating as it is possible for it to stop working unknown to the owner.

Recuperative exchangers may be divided into two categories:

1. Those for which the supply and exhaust air, or liquid, streams must be brought to the same place to go through the transfer medium.
2. Those which employ a fluid transfer medium which can be pumped from one location to another some distance away.

In both types precautions are taken to prevent any mixing of the supply and exhaust streams but at the same time keeping each stream in contact with the transfer medium as long as possible. In this way efficiency of heat transfer is maximized and only the Btu are exchanged.

Since heat transfer is mainly a surface function, the more surface exposed to each stream, the higher the efficiency.

Let us look at some of the available types of heat reclaim equipment and observe their characteristics.

Figure 1 Oldest and most common is the Heat Wheel, or rotary heat exchanger. First developed about 1900 by Dr. Ljungtstrom in Sweden, it has been in constant use preheating combustion air in large boilers with heat derived from the exhaust stack.

Recently, smaller models have been developed for ordinary air-handling systems and lower temperature differences.

Figure 2 The wheel is divided into sectors which are filled with metal wool. Aluminum, steel and stainless steel are used depending on the characteristics of the exhaust stream. The sector dividers provide structural strength and the wheel is slowly
Figure 3 rotated by a chain driving through the axle, or by a belt around its circumference. There is even a wheel, having no axle, which simply rests on a set of motor driven rubber rollers. Whatever driving means is used, an electric motor of small horsepower only is required.

The thickness of the wheel is much the same for all makes as this controls the pressure drop which is desireable to minimize. But the volume the wheel will handle determines the diameter. A wheel
Figure 4 built to handle 50,000 cfm would be at least 12 feet in diameter.

Figure 5 Another type of wheel utilizes honeycombed or corrugated metal as the heat transfer medium. This type will freely pass particles up to 100 microns in size which makes it useful in dusty atmospheres without the need to filter the exhaust stream.

This recovery system requires that all exhausts from which heat is
Figure 6 to be recovered be brought to one location, so that the total
Figure 7 exhaust will be made to pass through one-half of the wheel. Similarly all of the supply air must be passed through the other half
Figure 8 of the wheel before being distributed to its final destination. The transfer of heat takes place as the medium in the wheel rotates slowly through the hot exhaust and then through the cool supply picking up heat on one side and giving it up on the other. Where the temperature difference is high enough, efficiencies of 80% are realized.

All wheels allow some cross-contamination to take place. Some exhaust air leaks back into the supply side through seals, the effectiveness of which is a function of the pressure difference across the ducts; some is entrained in the transfer medium and carried from one duct to the other as the wheel rotates.

Cross-contamination can be controlled by properly arranging the location of supply and exhaust fans to make the pressure on the exhaust side negative with respect to the supply side and by use of a purging unit. This is a small pie-shaped blind section, which causes some of the supply air to blow out or purge, the trapped air in the wheel through the exhaust as each segment of
Figure 9 the wheel passes the purging unit. Carry-over of less than 1%
Figure 10 can be achieved with only a small loss in efficiency.

Finally, since the two ducts are located so close together, care must be taken outside the building to ensure that exhaust does not
Figure 11 get back into the intake. This is usually done by separating them as far as possible.

Obviously then, a heat wheel can recover heat from any exhaust that can be made to pass through it.
Figure 12 However, the material in the wheel does limit the temperature. Wheels filled with aluminum metal mesh or corrugations are limited to 300°F. Stainless steel will usually go to 600°F. Above that, ceramic material is used, but even it has an upper limit of about 1500°F. At this temperature, the main problem is to find flexible material with which to seal the wheel and it is
Figure 13 very difficult to match the expansion factors of a ceramic wheel to a steel axle and steel shell. Another limitation is size as the largest ceramic wheel is only 4 feet in diameter. The best solution is to reduce the temperature of the exhaust by mixing it with cold air to about 5-600°F where standard high-temperature wheels can handle it very easily.

A typical application of a heat wheel might involve making use of the high-temperature exhaust of some process to heat a large space in a building. In this example both the air volumes and the temperatures involved are very different. We see that the process exhausts 11500 scfm of gas at 400°F. If exhausted through a heat wheel supplied with an equal volume of outside air at 0°F, 80% of the heat will be carried into the fresh air stream heating it to 320°F. But the building space needs 50,100 scfm of fresh air at 80°F. So a by-pass duct containing a damper controlled by a thermostat downstream allows the addition of up to 34,600 scfm at 9° to mix the hot fresh air to produce the building's requirement.

Figure 14

As mentioned earlier it is sometimes necessary to reduce the temperature of an exhaust gas before it is allowed to pass through a recovery wheel. This next example involves a process exhausting 8680 scfm of 800°F gas and which needs an equal amount of fresh air preheated to 445°F. The hot exhaust is reduced to 556°F before it reaches the wheel by taking with it 4,320 scfm of 70°F air drawn from the building space. The wheel now supplied 13,000 scfm of air heated to 445°F of which the required amount to supply the process is split-off and the remainder is used elsewhere, either for preheating air for some other process or combustion device or used for building heat by additional dilution with outside air.

Figure 15

This could result in some complicated duct work, but this cost would be amortized by the reduction realized in fuel consumption in very few years.

Turning now to other types of heat recovery devices - still in the air-to-air category - we have two static devices, that is they have no moving parts.

Figure 16 The first of these is the Baffle Type, which is similar to the plate type liquid exhanger, see Fig. 21. Parallel plates, made of various metals are sealed from each other so as to keep the air streams separate. Heat transfer occurs by conduction and there is no cross-contamination. Because of the large channels created there is very little resistance to flow of gases or need for cleaning. Cleaning, however, is more critical than for the wheels, and the efficiency of heat transfer is lower - about 70%.

Figure 17 Counter-flow and cross-flow types are available. The use of coated steels and stainless steels can permit operation at 750°F and 1500°F respectively with only a 5% loss in efficiency over normal
Figure 18 aluminum metal. Some of these units are interesting in that they can be stacked in many ways to increase transfer, reduce pressure drop, or accommodate higher flows.

Another static device is called a "Heat Pipe" because it is a pipe
Figure 19 that will transfer heat. So, too, will any pipe made of metal - if you heat one end, the other end will eventually heat up through conduction. The heat pipe, however, uses a fluid sealed inside the pipe which vapourizes when heated and moves quickly to the cold end where it condenses. The liquid condensate then runs back to the hot end by capillary action, assisted by gravity (for the tube is usually mounted on a slant, or even vertically). It is thus able to transfer heat faster and in much larger quantities than conduction because advantage is taken of the latent heat of vapourization.

The medium usually used is Freon Liquid for low-temperature work, but obviously any liquid would work providing there is enough heat to vapourize it. Even solids can be used and heat pipes have been built using sodium metal, lead and even exotic metals which vapourize at a temperature higher than 2000°F. However, the construction and sealing of such devices becomes exceedingly difficult and an upper limit of 500°F is all that is practical.

Figure 20 In use, indivdual heat pipes are bundled into standard frames, with a divider to separate the hot and cold gas or liquid streams. It is interesting to note that the divider can be placed off-centre to accommodate unequal air volumes if desired. Construction of the tubes usually uses copper or aluminum, but, of course, they can be made of any metal to accommodate various temperatures. They can be finned to increase heat transfer and they can be coated to resist corrosive gases.

Efficiency of heat recovery is influenced by the number of rows of heat pipes, fin spacing, stream-flow rate and temperature difference. It varies from 50% to 70%.

Liquid to liquid heat exhangers have been in use for a long time and one usually thinks of the familiar shell and tube type of which there are many variations and much available knowledge. Some recent improvements to this technique have resulted in the development of methods to gain higher rates of heat transfer and more resistance to leaks and corrosive attack as well as the ability to handle higher temperatures.

Figure 21 The Plate Type heat exchanger uses single sheets pressed from very thin alloy steel which are then stacked on a frame with gaskets between the plates and compressed to form channels through which different temperature liquids can flow without mixing. Heat is transferred by conduction and since the metal is very thin, the efficiency is very high. The liquids move in counter flow with
Figure 22 the plate in between. For cleaning, dirt can be flushed out by reverse flow or they can easily be disassembled. The complete assembly, can be made in many sizes by simply varying the number of plates. Leakage is controlled by the gaskets and, as long as the plate is intact, must leak to the outside where it can readily be seen.

Figure 23 Operating temperature is limited to 400°F (200°C) by the gasket material. The plates can be stamped from titanium metal for extreme corrosion resistance. This type has the highest transmission rate known, it can exceed 1000 Btu per hour per sq. ft. per °F temperature difference (300 watts/sq. ft. °F).

Figure 24 The Spiral heat exchanger consists of two metal strips wound around each other with a space between. This makes two concentric channels in which the hottest medium normally flows from the center to the periphery and the colder medium in the reverse direction. Because one side of the channels can be sealed by welding and the other by a bolted-on gasketted cover, this exchanger can handle liquids up to 1300°F (700°C). However, efficiency is lower than the plate type and coefficient of heat transfer is only half as good at 500 Btuh/sq.ft.°F (145 watts/sq.ft°F).

Pipe connections and appearance are shown in this exterior view. They are practically non-fouling and easily opened for cleaning if necessary.

Figure 25 The Lamella designed heat exchanger replaces the familiar shell and tube type with some sophistication in the use of formed and seam-welded steel plates inside a pipe. Additional welding of the end fittings improves the sealing. It makes a nice packaged unit
Figure 26 and the efficiency is better than the standard shell and tube units. Because of the small channels, they are not so good with viscous or dirty liquids - they can only be cleaned by chemical means - but they are very good with gases.

Another variation of the shell and tube exchanger is one in which
Figure 27 the tubes are made of Dupont teflon. A great many small bore tubes are placed inside the shell and it is designed to handle extremely corrosive liquids. But because of the low conductivity of the plastic tubes, the efficiency is very low and so is the coefficient of heat transfer. One serious limitation to their use

is that as the temperature is increased, the operating pressure must be reduced.

A fairly new device uses the fluidized bed principle where shallow beds of aluminum-oxide granules can handle temperatures up to 1800°F and transfer heat from hot gas streams to a liquid four times faster than a shell and tube exchanger.

Figure 28 Waste Heat Boilers are normally used to make steam or hot water from hot gases, up to 3000°F is possible, which would normally be exhausted to atmosphere. As such they are very useful if you have a use for their output and would eliminate the need for a separate
Figure 29 fuel-fired device. They are usually constructed like any other boiler except that they are designed to utilize the temperatures that are inherent in exhaust gases rather than the higher temperatures produced by a flame.

Now all of the above devices are characterized by the fact that both the medium gaining the recovered heat and the exhaust medium supplying the heat must be brought to the same place and passed through the same device. This can at times be awkward and
Figure 30 expensive. The well-known run-around system of heat recovery gets around this by pumping a heated (or cooled) medium between two exchangers. The exchangers, which can take many forms and must be of the liquid type, may be placed anywhere in a building or buildings. A pump drives a transfer liquid through interconnecting pipes. Such systems must be custom designed and while their usefulness is readily apparent one must be aware that their efficiency is low, in fact, cannot be higher than 50%. Their temperature is limited to the available heat transfer liquids, such as ethylene glycol or dowtherm which can be used up to 700°F (375°C).

All of the previous heat exchangers recover heat at a lower
Figure 31 temperature than the waste heat temperature. But the "heat pump" is a device which can deliver heat at a higher temperature than

the source and at efficiencies greater than 100%. It too, can handle its heat source separated by some distance from its delivery point, as its primary circuit consists of copper lines carrying refrigerant. Additional energy in the form of electricity must be added to the system to run the pump or compressor, but this too becomes available as an internal source of heat.

The ordinary heat pump will recover heat from any source down to the freezing temperature of water and will deliver an output of as much as four times the electrical energy put into it at temperatures up to 130°F. For higher temperatures a two-stage compressor
Figure 32 is now available which can produce an output temperature of 230°F with an electrical input of approximately one-third of that required with fossil fuels. This raises the possibility of recovering useful heat from low-grade sources, of which there are many in industrial plants.

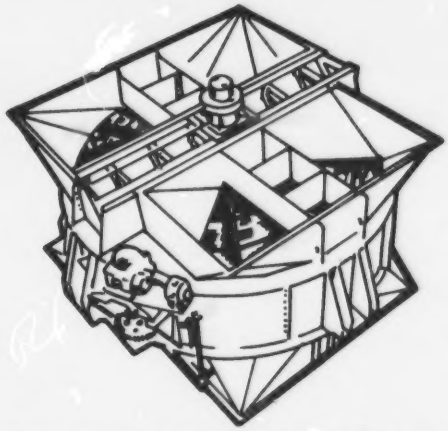
One must remember that with all heat pumps there are two loops,
Figure 33 one identified as the evaporator circuit and the other as the condenser circuit. In the evaporator, the source fluid is cooled and in the condenser, the delivery fluid is heated. The Btu needed for heating are transferred from the source fluid to the delivery fluid by the refrigerant medium which is continually being changed from a gas to a liquid by the compressor. We must not think that the source fluid is heated up to the temperature of the delivery fluid. The two loops are quite separate and the result is that when one loop is being heated up, the other loop is being cooled down. Therefore, attention must be paid to the lowest temperature to which the cooled source liquid can go without solidifying and to the hottest temperature that the delivery loop can reach within the gas pressure constraints of the refigerant medium.

The Coefficient of Performance (C.O.P.) of such a system is given as the ratio of output of the delivery loop in Btu to the elctrical input in Btu. This figure is normally better than 3 and increases as the temperature of the source of heat increases.

There are probably many other types of heat exchangers known today in addition to those covered here. There are the main types that are commercially available and obviously considerable engineering knowledge is involved in their design, construction and use. They are not cheap but they can recover and re-use a large portion of the energy we waste every day. I strongly recommend them to you.

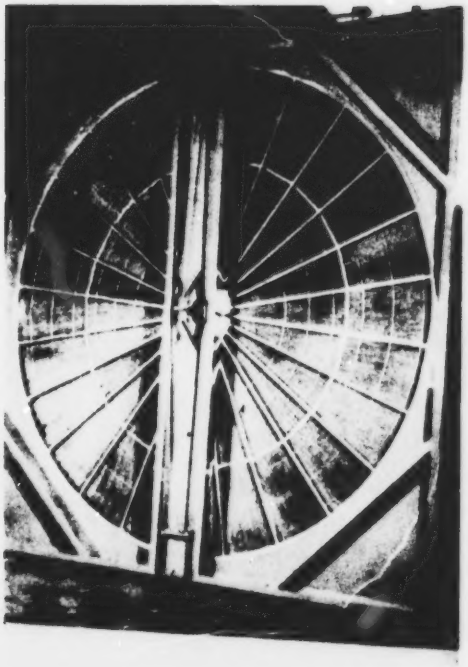
B.W. Robinson, M.A.
Energy Conservation Division
Ontario Hydro

Fig. 1

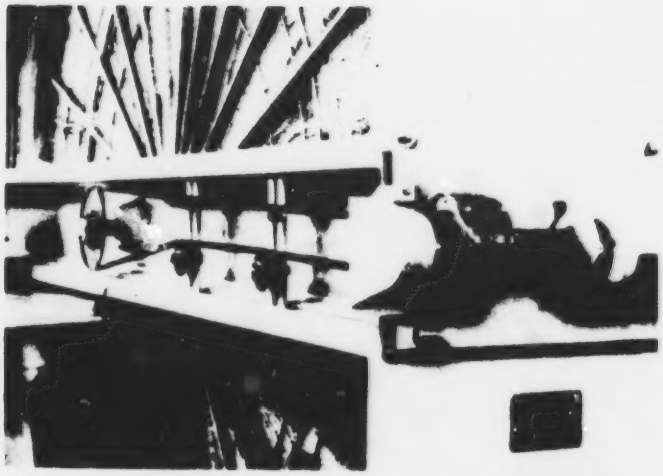


Rotary regenerator uses metal plates packed in the rotating wheel to pick up heat from exhaust gases and transfer the heat to warm incoming makeup air.

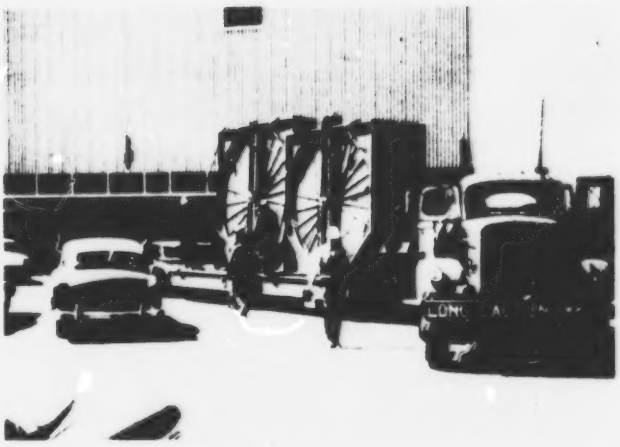
GAS-TO-GAS HEAT EXCHANGERS



HEAT WHEEL
Fig. 2

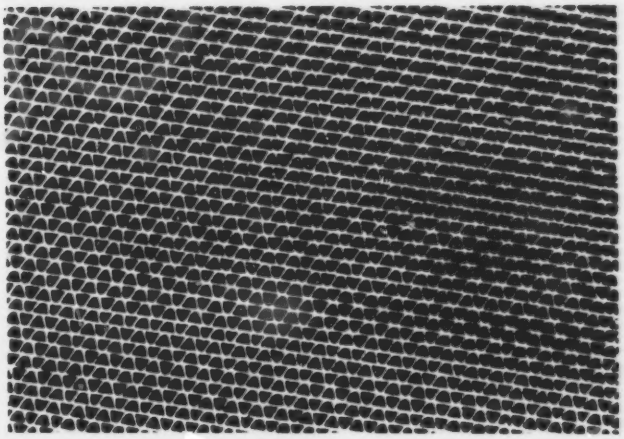


HEAT WHEEL
Fig. 3

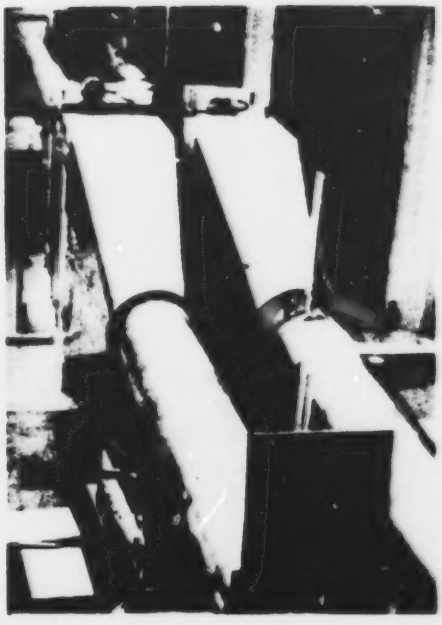


HEAT WHEEL
Fig. 4

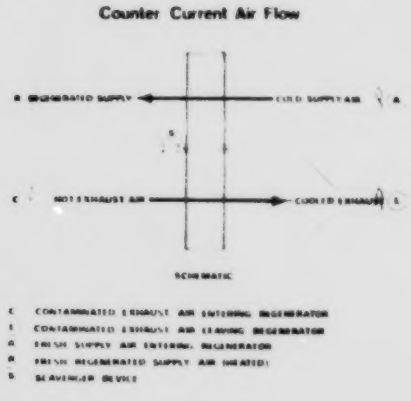
HEAT WHEEL
Fig. 6



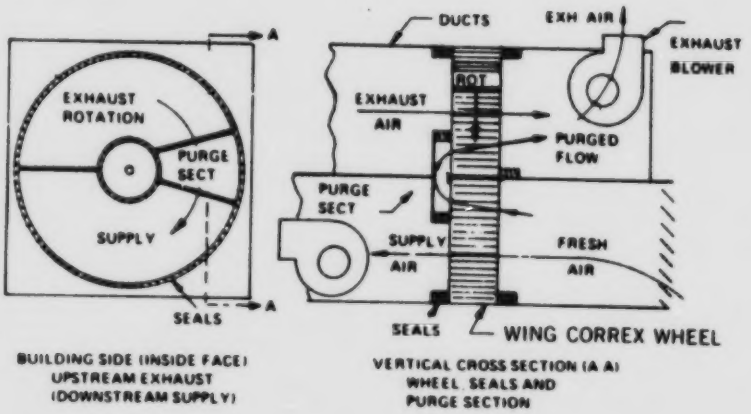
HEAT WHEEL
Fig. 5



HEAT WHEEL
Fig. 7



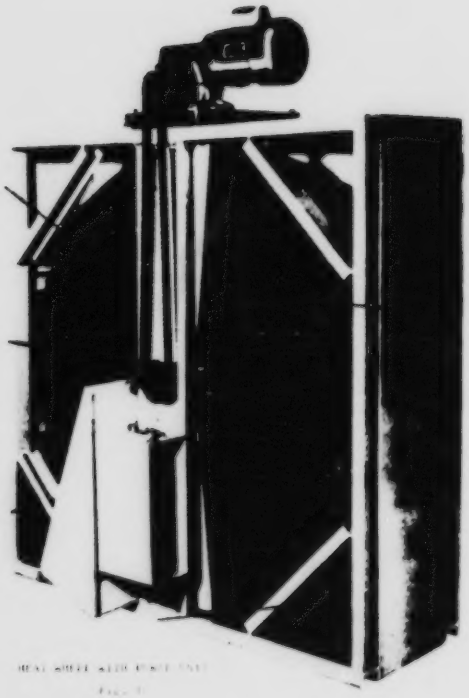
HEAT WHEEL
Fig. 8

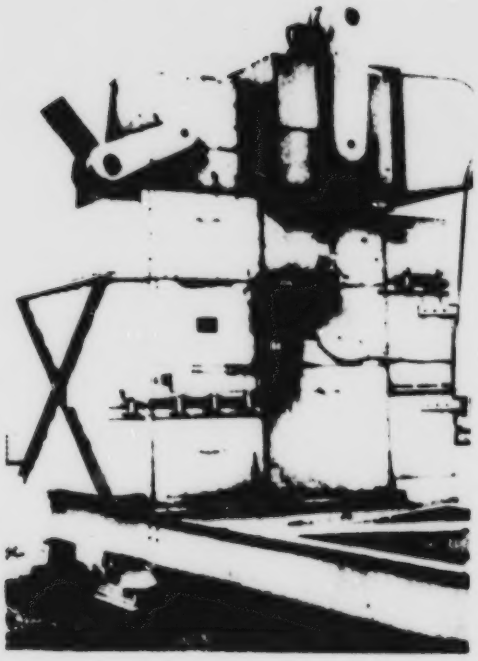


BUILDING SIDE (INSIDE FACE)
UPSTREAM EXHAUST
(DOWNSTREAM SUPPLY)

VERTICAL CROSS SECTION (A A)
WHEEL, SEALS AND
PURGE SECTION

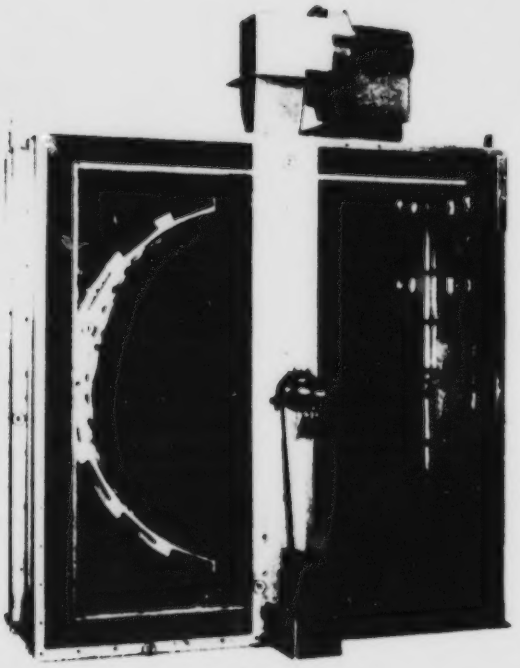
Fig. 9





HEAT WHEEL INSTALLATION

Fig. 11



CORTEMP ENERGY RECOVERY WHEEL

STAINLESS STEEL (600°F)

Fig. 12

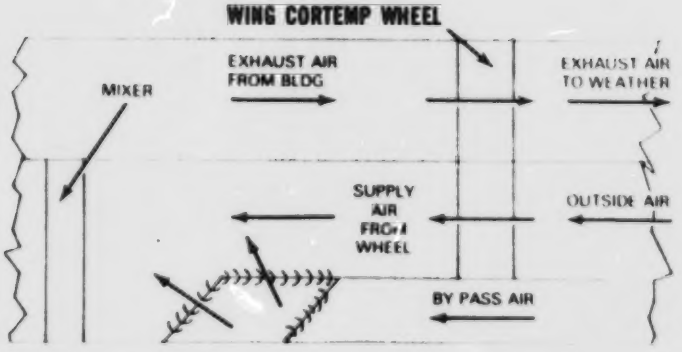
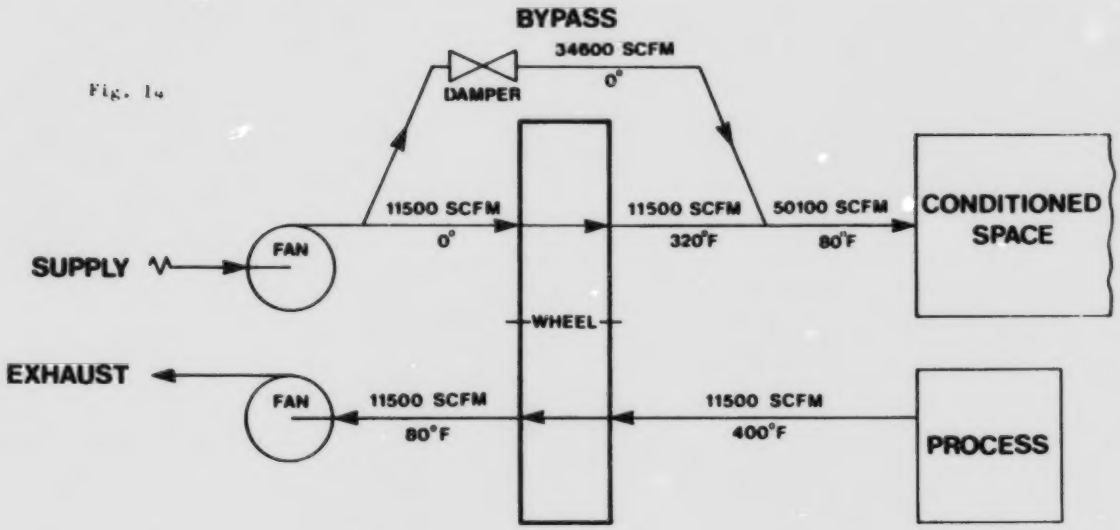


Fig. 13

Fig. 14


BYPASS
34600 SCFM
0°
DAMPER
11500 SCFM
0°
11500 SCFM
320°F
50100 SCFM
80°F
CONDITIONED SPACE
SUPPLY
FAN
WHEEL
EXHAUST
FAN
11500 SCFM
80°F
11500 SCFM
400°F
PROCESS

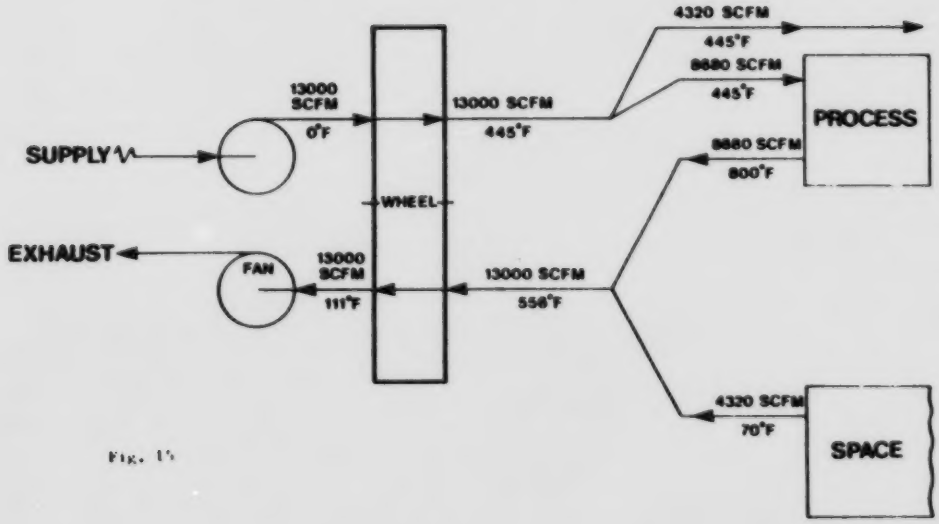

4320 SCFM
445°F
8680 SCFM
445°F
PROCESS
13000 SCFM
0°F
13000 SCFM
445°F
SUPPLY
8680 SCFM
800°F
WHEEL
EXHAUST
FAN
13000 SCFM
111°F
13000 SCFM
558°F
4320 SCFM
70°F
SPACE

Fig. 15

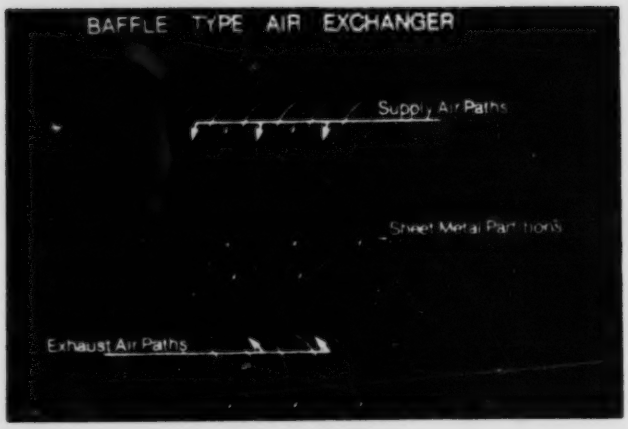
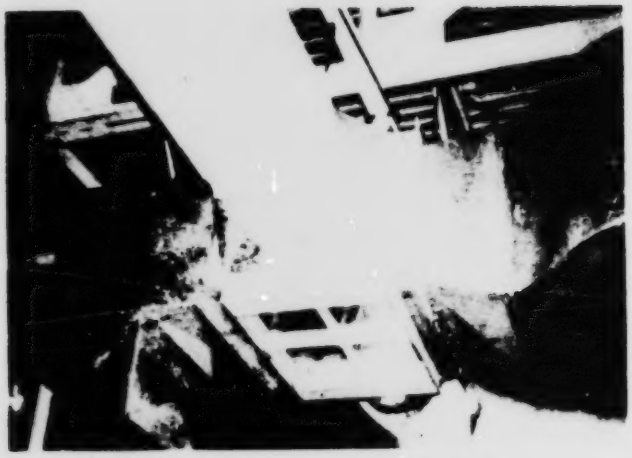
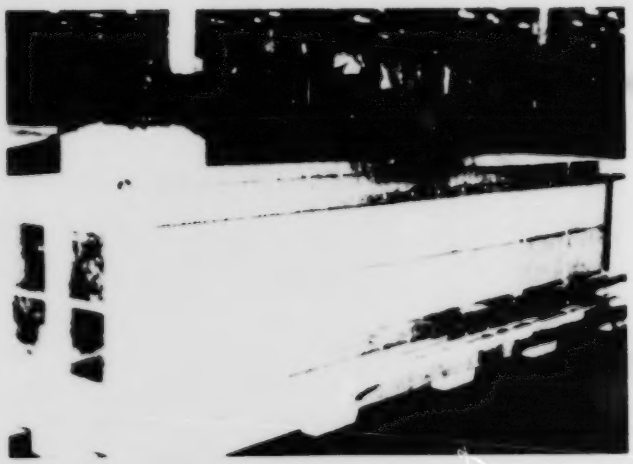


Fig. 16



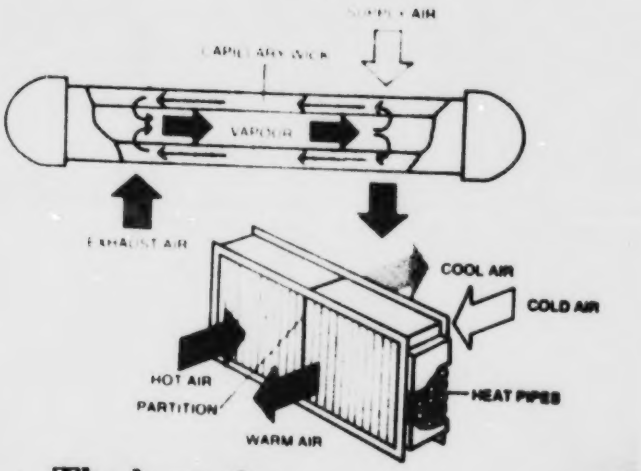
CROSS FLOW BAFFLE EXCHANGER

Fig. 17



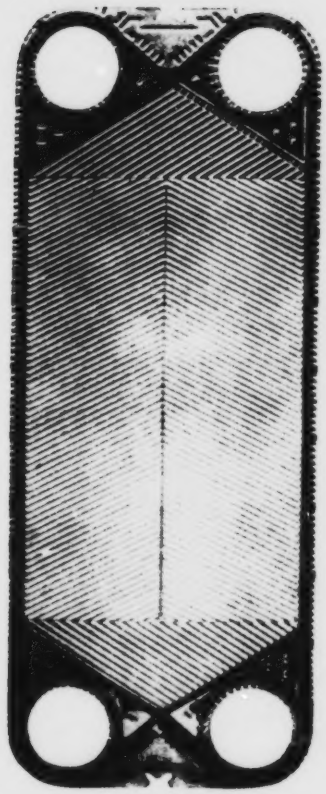
MODULAR BAFFLE EXCHANGER

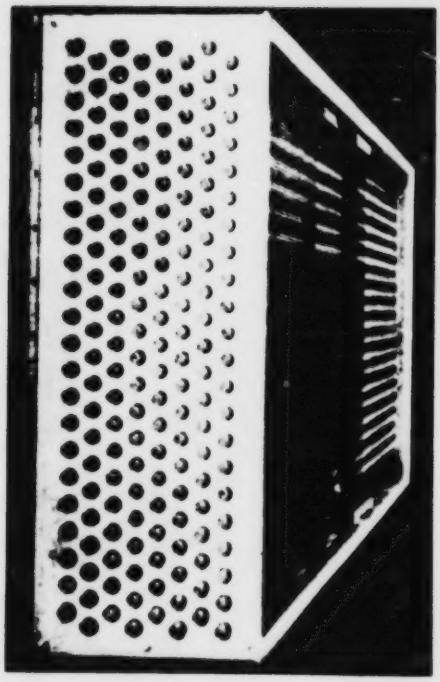
Fig. 18



The heat pipe

Fig. 19





HEAT PIPE

Fig. 20

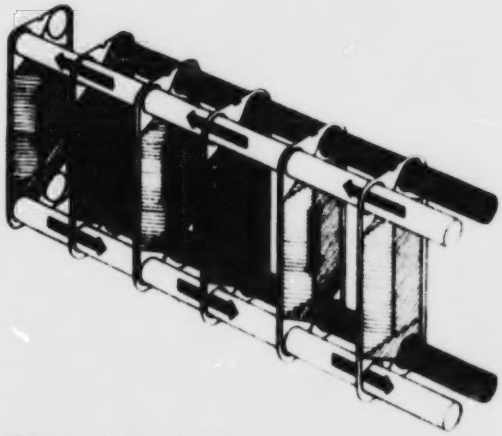
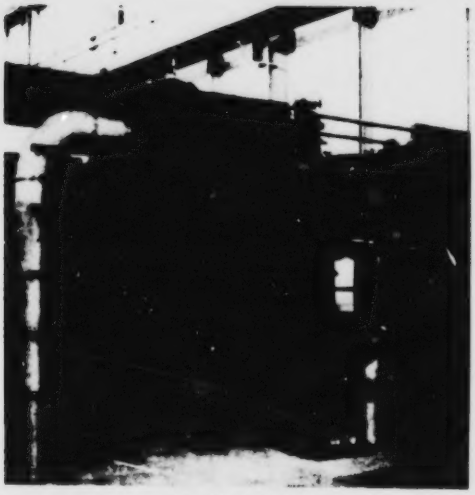
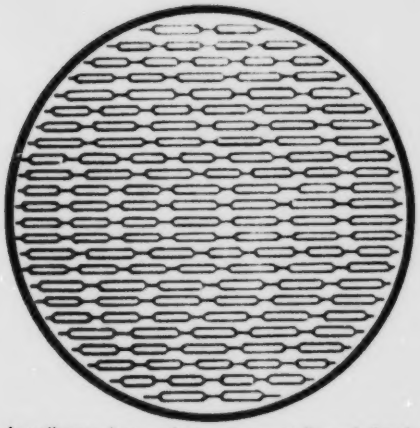


Plate-type heat exchangers use corrugated plates close together for heat transfer. Plates handling the hot and cold fluids are alternated

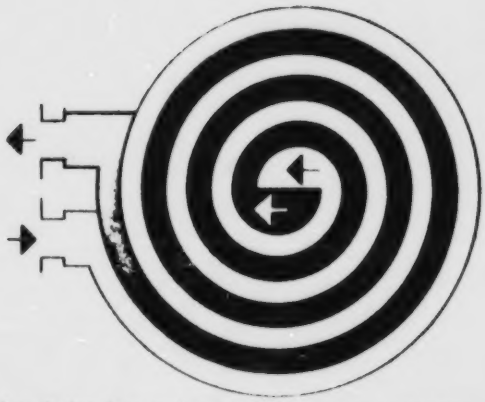
Fig. 22





Lamella-type heat exchanger is essentially a shell-and-tube exchanger using formed plates instead of tubes. This gives extra design flexibility.

Fig. 25



Spiral plate heat exchangers minimize flow restrictions. Metal plates are formed into a spiral, so flow may be parallel, counterflow or crossflow.

Fig. 24

Lamella design

Fig. 26

Construction of Du Pont's standard Teflon exchanger

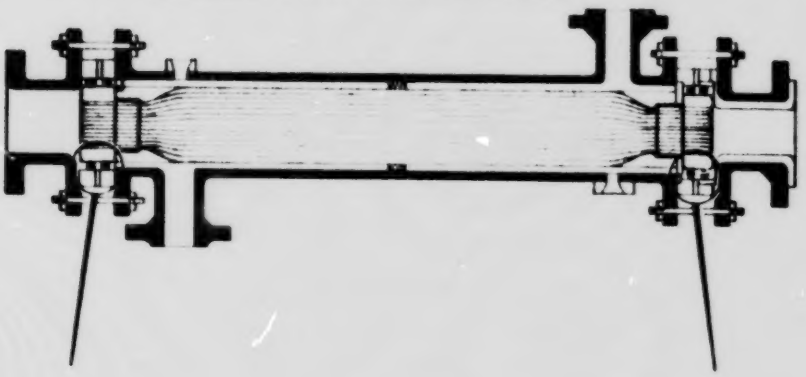


Fig. 27

Eclipse Heat Recovery Boilers

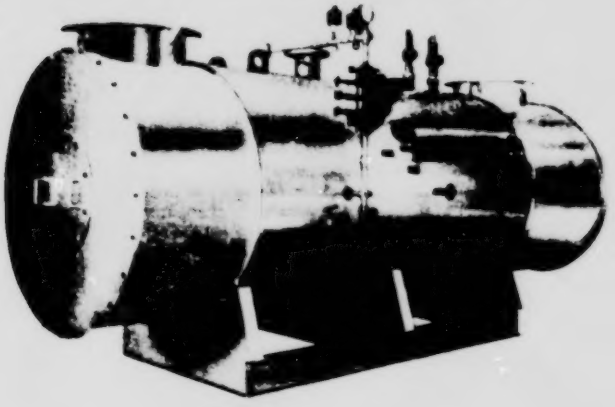
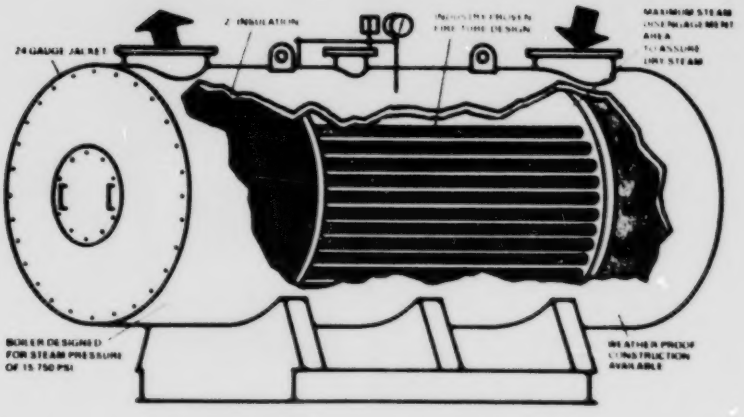
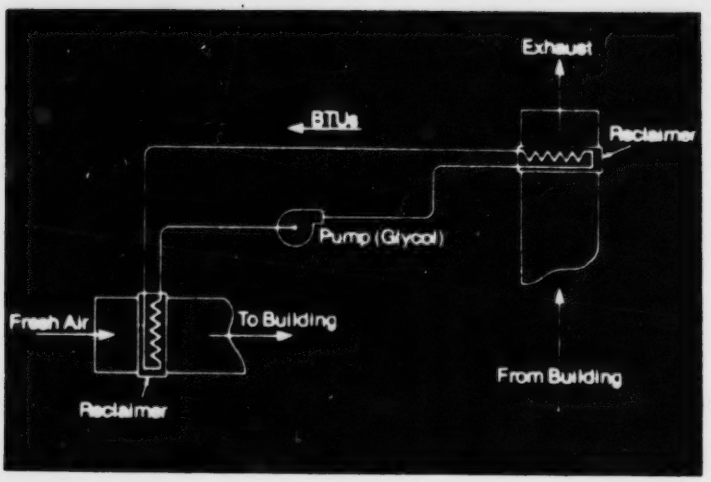


Fig. 28



WASTE HEAT BOILER

Fig. 29



RUN-AROUND
Fig. 30

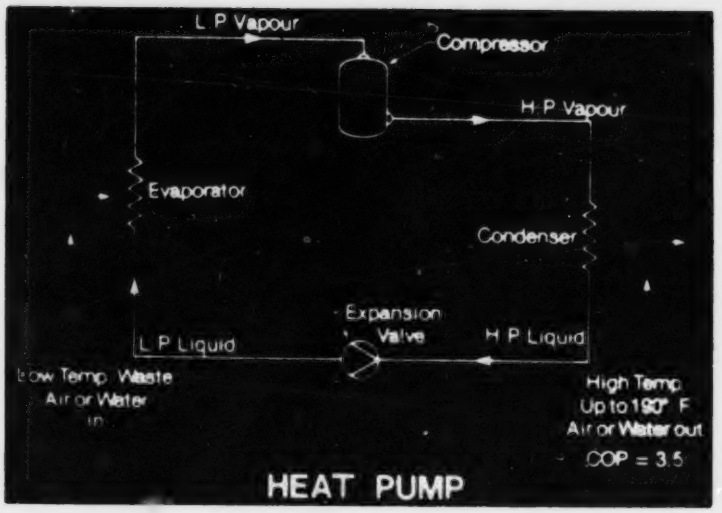
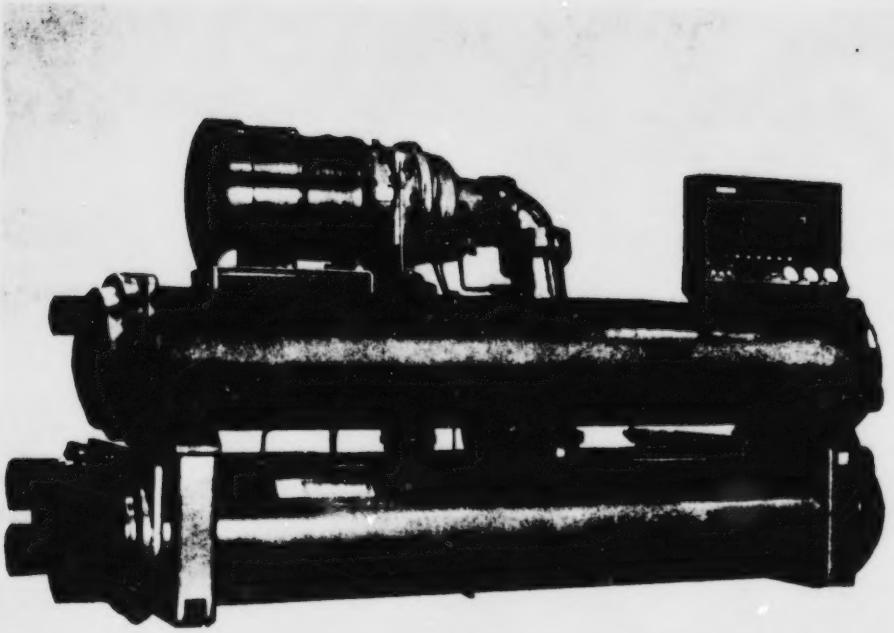
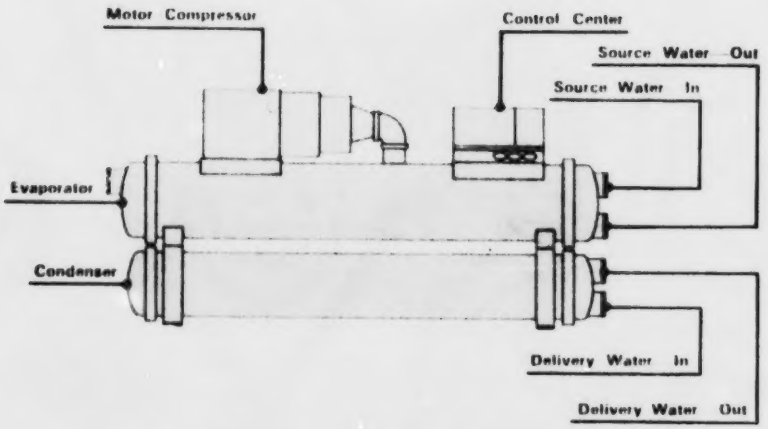


Fig. 31



HEAT PUMP
Fig. 32



HEAT PUMP
Fig. 33

THE ENERGY SITUATION

by

Roy Hislop

I have been asked to speak on the energy situation both on the international scene and in particular, as it affects us here in Canada.

The whole situation with respect to ENERGY has become a very complex subject and it will be impossible to cover all aspects in the 45 minutes that I have been allocated today. All I can hope to do, is to sort out the rumours, speculations and assumptions and try to give you a broad, factual picture of what faces this nation in the years that lie ahead in so far as it affects the energy situation.

As all of you know, it was in the Middle East in 1973 that the entire energy troubles really began. Prior to that time, all forms of energy were in plentiful supply and comparatively cheap, but in the intervening years the situation has undergone some drastic changes. The first thing that happened back in 1973 was that the Organization of Petroleum Exporting Countries, commonly known as OPEC, began to escalate the price of CRUDE OIL, and once the price of oil began to rise, so did world inflation.

Since 1973 the price of oil has continued to increase on a yearly basis and the latest report is that Saudi Arabia has proposed a plan under which OPEC would change oil prices <u>four times a year</u>, based on the fluctuations of currencies, inflation in major western countries and in the rate of economic growth in those nations.

<u>WARNING FROM SAUDI ARABIAN OIL MINISTER</u>

A word of warning of the use and future availability of oil, was recently issued by Sheik Ahmed Yamani, Saudi Arabian Oil Minister, at a speech in Toronto. He warned that existing world oil supplies can support current world production for only 30 years and governments which shield consumers from that reality with price subsidies, only harm their long term interest. The Oil Minister also said that soaring energy prices in the last seven years had encouraged conservation but there was still too much waste

and that oil, the scarcest energy resources, must receive priority in conservation practice.

At present, Canada imports about 450,000 barrels of oil a day (and that's a lot of oil) with about 37 percent of that oil coming from Saudi Arabia, which in turn controls about one-third of the total production from OPEC.

I think, these words of the Arabian Oil Minister stress the vital importance of conservation, but you will be hearing more about that later.

Also of great concern to all of us should be the volatile and uncertain situation existing in the Middle East, the way things are today; what with the American Hostage crisis, Russia on the border of Iran, the escalation of the war between Iran and Iraq; any of these could develop into a major situation resulting in a drastic reduction in the vital oil supply to the rest of the world. Already the Iraq-Iran war has disrupted the flow of oil to twenty countries, particularly France. There is a possibility of the war in the Middle East spreading to other countries, which could have disastrous results on the world oil supply.

The words of the Oil Minister from Saudi Arabia, the volatile situation in the Middle East, all point to the importance of this country becoming self-sufficient in energy as soon as possible.

CANADA

Now, how does this affect us here in Canada; well, many years ago it was decided that WEST OF THE OTTAWA VALLEY, the Canadian Provinces would use CANADIAN OIL and EAST of the OTTAWA VALLEY imported oil would be used, which in those days was very cheap.

This OTTAWA VALLEY demarcation line still fundamentally exists so that, in effect, the people of Quebec and the Maritimes are burning imported oil from the Middle East and Venezuela at around $36-$38 a barrel, while the rest of Canada are using Canadian oil at $16.75 a barrel.

As it would be unfair and politically fatal to any party to allow such a situation to exist, the Federal Government pays a subsidy to bring the cost of oil in the eastern half of Canada in line with the price being paid in the west.

The money for these subsidies, which is estimated to be over $4 billion, the Federal Government obtains from general tax revenues.

Alberta, the main oil and gas producing province, with the support of most of the provinces, wishes to bring the price of Canadian oil to within 85% of world oil price as soon as possible.

The cost of CANADIAN OIL has been increasing at the rate of $2.00 a barrel per year for the past few years.

The Federal Government in its recently announced Budget, plans to increase the cost of CANADIAN OIL by $4.50 per barrel in 1981, 82 and 83. In addition to this $4.50/barrel increase, there could be a possible SYNCRUDE LEVY that will drive the annual increase of oil even higher. Then there is also the possible ENERGY LEVY on both gas and oil. The Federal Government is considering this ENERGY LEVY as a means of raising the billions of dollars that it will require to take over some of the multi-national oil companies in the west.

Just taking into account the $4.50 per barrel increase, the price of Canadian oil will be at least $31 a barrel by the end of 1983. (Up from $16.75 November).

We must bear in mind that at the same time as an effort is being made to close the gap between the World Oil Price and the Canadian Oil Price, the OPEC countries will continue to demand higher prices each year for their "liquid gold" - oil.

PRICING OF NATURAL GAS

The Federal Government decided some years ago to peg the price of natural gas at 85% parity with crude oil at the Toronto City Gate. So that when the price of oil is increased by $1.00 a barrel, gas goes up by 0.15¢/Mcf. That 85% parity is to be decreased to 71% by 1983.

Incidentally, for those of you who are working on your energy budgets and are wondering about future price increases this year, our best guess was:

March 1980	-	15¢ per MCF
August 1980	-	30¢ per MCF
November 1980	-	15¢ per MCF

Our predictions for the March and August increases of 15 and 30 cents per Mcf have been dead on.

The September figure of 15¢ per Mcf has been increased by the recent Budget to 30¢ per Mcf effective November 1, 1980.

We had been predicting the following increases for 1981, but once again the Budget has made changes.

February 1981 - 30¢ per MCF

August 1981 - 30¢ per MCF

Future natural gas price increases laid down by the Budget are as follows:

November 1/80	-	30¢ per MCF	(Gas tax)
July 1/81	-	15¢ per MCF	(Gas tax)
January 1/82	-	15¢ per MCF	(Gas tax)
February 1/82	-	15¢ per MCF	Well head $1 barrel on oil
August 1/82	-	15¢ per MCF	Well head $1 barrel on oil
January 1/83	-	15¢ per MCF	(Gas tax)
February 1/83	-	15¢ per MCF	Well head
August 1/83	-	15¢ per MCF	Well head

With the proposed oil price increase schedule announced, the overall effect will be the widening of the price differential between the cost of oil and natural gas.

Gas will become correspondingly cheaper in relation to oil.

The current 85% parity of gas to oil is also to be gradually lowered to 71% parity, thereby making gas even lower in cost than oil. This is a definite plan of the government to encourage the switch to natural gas.

ALBERTA TAR SANDS

Before we leave the question of oil, let's turn for a moment to the Alberta Tar Sands, which could become a major source of Canadian oil in the future, but it will be expensive oil, due to the difficulties and the expense of removing the oil from the tar sands.

In order to encourage this costly process, the Federal Government had agreed and had been paying the producers WORLD OIL PRICE for the oil reaching market from the tar sands. That subsidy was subsequently cancelled by the Federal Government, much to the dismay of the companies operating this difficult and costly project.

Recently, the chairman of the Board of Imperial Oil threatened to "pull the plug" on its $8 billion Cold Lake oil sands project if Ottawa and Alberta don't soon reach agreement over the price of oil.

At stake is a project which would produce 10% of Canada's oil by 1990 and which is expected to have a major economic impact across Canada, creating jobs and triggering an estimated $1.8 billion in extra household income by 1986 in Ontario alone.

Also, Alberta has refused to allow any further oil sands developments until it gets an agreement with the Federal Government on the price of oil.

OIL SITUATION IN CANADA

Canada's imports of crude oil are some 5% of those of the United States. In 1977, Canadian per capita consumption of energy was 8.7 tons of oil equivalent, compared with 8.3 tons in the U.S. In terms of per capita, Canada leads not only the United States, but, in fact, the world. When you tie these facts in with the fact that Canada's oil production is declining in relation to the increasing demand, we are faced with the situation that means, we either find more oil within Canada or import more from overseas, thereby worsening our balance of payments. There are fortunately two solutions to the problem, Natural Gas and Conservation which I will be speaking about later.

FRONTIER AREAS

There have been discoveries of oil in the Arctic and frontier areas, but the problem is bringing that oil to market. Likewise, oil has been found in commercial quantities in the New Hibernia oil field under the Atlantic off the shore of Newfoundland, but the hopes of the oil find in the nearby Beb Nevis well, which at first looked very promising, now looks pretty discouraging according to experts.

Indications are that conventional oil supplies will steadily decrease while oil from oil sands and offshore oil fields will not fill the gap. As you will, no doubt, agree, the situation does not look all that good, but at the conclusion of my presentation today, I will be suggesting remedies to overcome some of the problems facing this nation in respect to its energy requirements.

NATURAL GAS

Having covered briefly the oil situation, let's now turn to another major source of energy - NATURAL GAS, which fortunately happens to be in plentiful supply.

In February 1979, the NATIONAL ENERGY BOARD released its report "Canadian Natural Gas Supply and Requirements".

This report stated that a preliminary estimate indicated that natural gas proven reserves from CONVENTIONAL sources will last well into the 1990's.

This does NOT include the considerable discoveries in the MacKenzie Delta and Arctic Islands, which I will be talking about later.

Proven Reserves	72 TCF
Canadian annual usage	1.6 TCF
Annual Exports to U.S.A.	1.1 TCF
Annual Canadian Production	2.7 TCF

GAS FROM OTHER AREAS

The conventional area of supply is mainly within Alberta, and in north-west Canada, i.e. the MacKenzie Delta and the Beaufort Sea and the Arctic Islands.

Considerable finds of natural gas have been discovered already in these frontier areas and further exploration is proceeding at an increased rate. But, of course, the problem of bringing all this gas to market has still to be solved.

Off the eastern shore of Canada lies the Labrador Shelf and the Atlantic South Shelf, which experts believe will provide further natural gas reserves, including the gas fields already located on SABLE ISLAND.

LNG FROM THE ARCTIC

On this question of bringing natural gas from the Arctic Islands, it is interesting to note that Petro-Canada, the government owned oil company, plans to start shipping LIQUID NATURAL GAS south in 1985-86. Two large LNG tankers will initially be used to ship natural gas to ports on the coast of Canada and possibly the U.S.

To convert natural gas to LNG, gas is compressed at a temperature of -260°F, so that each cubic foot of LNG contains 600 cubic feet of natural gas.

On reaching the eastern seaboard, the tankers would discharge their loads into a re-gasification plant, where the LNG would be converted back to natural gas and fed into natural gas distribution systems to bring the gas westward from the east coast.

Now, we come to the most exciting area, The Alberta Deep Basin.

THE ALBERTA DEEP BASIN

Situated on the Alberta/B.C. border is the 30,000 square mile Alberta Deep Basin, which may prove to be one of the largest gas finds in North America.

Based on testing and analysis of over 500 gas wells in the area, experts consider that the Deep Basin contains 440 TCF of natural gas.

At current gas costs, it is estimated that 40 TCF is recoverable, but as the cost of the gas goes up in accordance with government decrees, more and more of the vast reserves can be tapped and brought to the market.

The main problem in the Deep Basin is that most of the reservoirs are porous, but the pores are not interconnected. Hence, fracturing by use of highly compressed special liquid sand, which is pumped many hundreds of feet underground, is needed to create circulatory channels in the porous rock formation in order to collect the gas reserves that lay buried there.

Of this vast potential reserve of natural gas, the National Energy Board at this time has only accepted 1 TCF in their total proven reserve figure of 72 TCF.

NATURAL GAS EXPLORATION - THE FUTURE

To sum up the natural gas position in Canada, we find that Canada's remaining conventional established reserves of natural gas have been increasing steadily over the past four years. This results from strong exploration and development activity spurred on by government programs. Gas well completions last year increased by 5% in Alberta and 10% in British Columbia over the record year of 1978.

Development in the Deep Basin area, which straddles the Alberta, B.C. border indicate the potential for large new volumes to be added to established Canadian reserves in the near term. Longer term potential for sizeable accumulations of oil and gas exists in the Arctic and the Atlantic and the offer our best hope for large additions to our supplies of conventional hydrocarbon energy.

THE BIG SWITCH

So, on the one hand, we see a very tight and uncertain oil situation facing this country, but to lighten the darkness, we find that we have an abundance of natural gas, so much so that the National Energy Board who are very conservative in their summation of the energy situation, have seen fit to grant export licenses to the U.S.A. over the next five years.

What has brought about this "gas bubble" as it has been referred to? Well, basically two factors:

1) Increased finds of natural gas.
2) The rapid escalation of the price of gas has made many gas wells that were at one time uneconomically viable, able to produce gas at a marketable price.

Due to the concern and uncertainty of future oil supplies for home heating, businesses and industries, we, in the natural gas industry, find ourselves in the words of this newspaper headline, coping with a stampede to switch to natural gas.

For example, whereas we normally convert 5,000 homes per year from oil to gas in our franchised area, this year we expect to convert 30,000 homes to gas heating.

In addition to the wholesale switch to natural gas in the residential market, we are finding that conversion of COMMERCIAL establishments has doubled or tripled in most areas.

What we are experiencing at Consumers' Gas is also occurring in many other parts of Canada where natural gas is available.

ONTARIO ENERGY BOARD

We, as distributors of natural gas, are closely regulated by government authorities in all aspects of our operations.

This is especially so with regard to the pricing of gas, which is controlled by the Ontario Energy Board.

ALL PRICE INCREASES

All increases in gas prices have to be approved at a Public Hearing of the Ontario Energy Board. The Legal Counsel for the Board, Consumers' Gas, the Industrial Gas Users Association and some of our major customers investigate every aspect of these submissions in great detail.

As a Public Utility our Rate of Return (or business profit) is fixed by the O.E.B. following periodical and lengthy hearings on our RATE BASE. Once the allowable rate of return has been established, rates are examined to ensure that they are fair and equitable for each class of customer.

Similar regulations and controls also exist in other parts of Canada.

THE HYDRO POSITION

The current and future supply situations in Canada with respect to the supply of electricity looks good, with some of the provinces being in a position to export hydro power to the U.S. and to other provinces. With most of Canada's hydro sites already tapped, future supplies of electricity will have to come from plants fired either by fossil fuels or from nuclear plants.

SUMMING UP THE SITUATION

From my foregoing remarks, it is apparent that the long term situation for oil gives cause for grave concern, not only from the supply situation, both with respect to imported oil and Canadian oil, but also in the financial area.

The Federal Government is presently subsidizing imported crude and heavy fuel oil in the approximate amount of 4.0 billion dollars per year.

To illustrate the overall impact of this subsidy in foreign oil, I would point out the original estimate was 2.5 billion dollars, but is now running at 80% over budget at 4 billion dollars. This represents a further drain on the public purse. This once again stresses the urgent need to reduce our dependence on foreign crude oil.

WHAT CAN BE DONE

Well, having listened to a brief synopsis of the "Energy Situation", let's now try to deal with the question of what can be done to solve the problem.

INCREASED USE OF NATURAL GAS

To reduce dependence on costly imported oil and to reduce our balance of payments, there should be an increase in the use of natural gas.

This is already occurring, as I have mentioned, but we are still only skimming the surface. The introduction of an incentive program will do

much to speed up the conversion of natural gas in those provinces where natural gas is available.

EXPANSION OF MAINS

Another step that can be taken is to expand present areas of natural gas distribution.

Natural gas is transported 2,800 miles from Alberta to Toronto, and then travels on to Montreal.

Consideration is being given to extend the TCPL from Montreal to the Maritimes, and the National Energy Board has already given the approval for the initial extension to Quebec City.

Incidentally, gas utilities in many areas are extending gas distribution lines to serve areas that are at present not being served, where there is an economic justification.

OBSERVATION

There is another important area where all of us at home and at work can play a significant role in helping Canada achieve "self-sufficiency" in energy, and that is through a determined effort by everyone to conserve energy.

Yes, CONSERVATION is a very important word nowadays and it is a subject that is receiving close attention by governments and industry.

Can conservation work? The answer is a definite YES, it can be of great help to enable Canada to win the Energy Battle and also to save many thousands of energy dollars.

To prove my point that conservation is working and that energy dollars can be saved, let's take a quick look at some of the results being obtained.

1. Federal Government buildings in Ottawa - up to 40% reduction in energy use.
2. Ontario government buildings - $1.5 million saved in energy costs over a 2-year period.
3. High-rise commercial buildings in downtown Toronto have saved $2.5 million in the past year by dimming lights and turning down thermostats.
4. York University has reduced its energy demand by 40%.

5. Many apartment buildings have reduced their gas usage for heating by 20% to 35%.
6. Many industries have also instituted conservation programs with varying degrees of success.

EXAMPLES

Here are some examples of how a variety of industries have reduced their energy usage, often by fairly simple means.

Infra-Red Heating

Cold spots in warehouses or buildings with bays and high ceilings can be extremely expensive to heat. For a heating system that warms people and not just large empty spaces, the experts recommend gas infra-red heating.

It's estimated that a properly designed infra-red heating system will cut costs by fifteen to twenty percent compared to warm air heat in the same installation. In view of savings like that, plant heating retro-fitting often makes good sense in dollars and cents.

Infra-red gas heating, which burns gas and air on the surface of ceramic or wire mesh panel in a unit heater, has long been popular in Europe and particularly in Germany. The move to energy conservation has awakened new interest in Canada.

$175 Timer Saves Energy

A Toronto Industry that was operating a special production line on THREE-shift basis, changed to a TWO-shift operation.

As there was a 45 minute "warm up" period required, the gas fired burners were left on during the non-operating THIRD shift period, resulting in a wastage of gas for approximately eight hours.

A $175 timer was installed to turn on burners 45 minutes ahead of the shift coming on duty, resulting in several thousand dollars of energy saved.

PLANNING FULL PRODUCTION LOADS - SAVES MONEY

Planning a full production load is often so simple - and yet it's surprising how few companies do it.

With planning, production can be loaded to full capacity when operating and, whether you are producing 100 widgets or 50 widgets per hour, energy losses are much the same. Thereby with a FULL load operation, both energy and labour dollars can often be saved.

One Toronto-area candy manufacturer has applied this method of energy conservation with good success, and considerable savings, to the refigeration of candy bars fresh from the chocolate encasing process.

A CASCADE OF SAVINGS

A Toronto-area gypsum plant recently reviewed its ore processing methods - and came up with sizeable savings.

The company employs two ovens to calcine and dry the raw ore. Each use a quarter of million BTU per hour. An energy consultant noted the fact that the ovens were only 100' apart and suggested that the products of combustion could be cascaded from one oven to the other.

Ducting was put in at relatively low cost and now heat from the calciner is cascaded into the dryer - eliminating the energy input to the dryer completely except during startup operations, and saving the company a bundle of energy dollars.

COMPANY CUTS HEAT LOSS, SAVES MONEY

A firm which manufactures aluminum structural extrusions recently looked at the performance of their caustic tanks. They were shocked to discover that most of the heat used in the process was being lost up the chimney.

The tanks were heated by natural gas fired immersion burners. The products of combustion were vented to an exhaust hood over the tanks.

The exhaust hood removed the caustic moisture laden air from the plant atmosphere very efficiently - but in doing so, it also drew off much of the heat. The products of combustion disappearing so rapidly resulted in a very short dwell time in the ten-inch tubes immersed in the tanks.

This very short dwell time in the tubes decreased the heat transfer between the products of combustion and the caustic solution and resulted in a flue gas temperature of about 1000°F.

The company found an easy solution to the problem. It arranged to have the immersion tubes vented to atmosphere by gravity. This simple change

lowered the flue gas temperature to 400°F and raised the combustion efficiency by 36% at a very low cost.

A further example cites the case where a home built in 1960 was using 170 Mcf of natural gas, whereas the identical design built to the most recent building code standards in 1980 would use only 120 Mcf - a 30% saving in energy due to the improved insulation standards now in force.

SUMMING UP CONSERVATION

As you can see from my foregoing remarks, conservation is saving MILLIONS of vital energy dollars each year in Canada, but this is only the start.

Greater emphasis must be placed on conserving ALL FORMS OF ENERGY in the years that lie ahead if we hope to achieve the goal of self-sufficiency in this century.

GENERAL SUMMING UP

To meet and overcome the energy problems facing this nation, certain steps must be taken now:

1. Increased exploration for natural gas and oil.

To maintain Canada's very enviable position, exploration for new sources of natural gas must be accelerated, and also the building of new pipelines to bring frontier gas to market must be financed and constructed as soon as possible.

2. Further development of the Oil Sands.
3. We need strong political guidelines to conserve oil and to substitute other energy forms, particularly as heating fuels.
4. Greater attention and encouragement of all means available to conserve our vital energy supplies.

CONCLUSION

Energy is a very complex subject and no one person has all the right answers, the experts cannot agree on many points, and even nations are uncertain as to how to handle this critical subject. I can only hope that during the past thirty minutes my remarks have shed some light on the subject of energy and, in particular, natural gas.

ENERGY CONSERVATION
THE VIABLE ALTERNATIVE

by

Walter Chic

The subject of energy conservation is vast indeed, encompassing every person in Canada - from the homeowner who turns down the thermsostat, to the managers of large office buildings, to the people who work in our industrial plants.

I have been asked to speak on the government's role in energy conservation, and I believe that this is done best by reviewing the need for energy conservation, and the methods through which energy efficiency can and has been achieved. I don't think I need to impress upon you the urgent need for energy conservation programs at all levels of our society; in recent weeks we have seen wild fluctuations in the world energy situation - in particular, the international petroleum market - and in recent days we have seen how sensitive our national situation is to energy pricing.

The long-term effects of the conflict between Iran and Iraq are yet to be felt. However, the short-term effects have been obvious.

To put it simply, in a matter of days, the western world went from the prospect of relative security of supply and price of crude oil, to the prospect of tight supplies, possible shortages and spiralling prices. Surely, we now have more than sufficient evidence that Canada must eliminate its dependence on foreign supplies of crude oil as soon as possible.

The Ontario Government believes that Canada can achieve - it must achieve - crude oil self-sufficiency by the end of this decade. It can be achieved in a combination of ways:

1. Increasing domestic crude oil production;
2. Substituting other fuels, preferably from renewable or recoverable sources, for petroleum, and
3. Reducing our consumption of petroleum - indeed, of all energy - through energy conservation.

It is on this third method that I would like to concentrate today.

The essence of conservation is sound energy management - using only as much energy as you need to do the job. There are at least two excellent reasons for conserving energy: to save money today, and to ensure security of energy supplies for tomorrow. What, then, is the role of the Ontario Government in energy management?

Our responsibility is to encourage and assist all sectors of our society in establishing and operating energy management programs, and to lead by example. We have demonstrated our leadership in a number of ways already. Earlier in October, the Minister of Energy announced a number of new programs as part of a five-year, $165-million energy package.

Typical of some of the initiatives undertaken by the Ontario Government, in 1976, working with the Ministry of Government Services, we established a five-year program of upgrading the energy efficiency of provincial buildings. Our target was to reduce energy consumption in these buildings by 15 percent. Our methods included modifying existing heating, air conditioning and ventilation systems; reducing lighting levels and lowering temperature settings in the heating season. Most important of all, we ensured that the buildings would be operated properly and the equipment maintained through a sound energy management program.

The results? We surpassed our targets after only two years of the program: Initial investments of $9-million have resulted in savings of almost $20-million - a more than 100 percent return. And these savings will accumulate and grow through the years, as the cost of energy rises. Early in October, the Ministry of Energy announced a $10.6-million, five-year extension of this program, with a target of achieving a further 7.5 percent reduction in energy consumption by 1985. In total, the Ministry expects to achieve savings of 26 percent in our government buildings. As well, the Ministry has budgeted $2.5-million for converting space-heating systems in government buildings from heating oil to other, more reliable and less costly, forms of energy.

At present, about 30 percent of the space-heating needs in buildings owned by the Ontario Government is supplied by heating oil. The Ministry of Government Services has identified 338 buildings which are suitable for conversion over the next five years, principally to natural gas.

Of particular interest are some of energy management programs we have in place to assist municipalities, and the commercial and industrial sectors.

First, municipalities. Our municipal energy program started in 1978. At that time, a joint Provincial-Municipal Steering Committee was established to offer advice and expertise to municipalities in such areas as building management, transportation, street lighting, urban planning and municipal waste disposal. At last count, 150 municipalities, representing 75 percent of the population of Ontario, had appointed energy coordinators and established energy management programs. Municipalities in Ontario now spend between eight and thirteen percent of their tax revenue on energy. For a municipality of 70,000 people, that's about a million dollars a year.

Some examples of what has been achieved are, to say the least, impressive.

- Kapuskasing reports a reduction in energy consumption of 12 percent, worth $9,000;
- the region of Waterloo reports savings of 13.5 percent, worth more than $100,000;
- Burlington has reduced energy consumption by 15 percent, worth $41,000 and
- the borough of Scarborough reports a full 20 percent saving; worth more than half a million dollars.

These figures, of course, include transportation, street lighting, building operation - all facets of municipal energy consumption.

The Ministry's new Municipal Energy Audit Program with funding of $3.6-million over three years, will further assist operations and establish or expand energy management programs. The Ministry is also establishing a $12-million, three-year program designed to share the costs of oil conservation and conversion projects with municipal governments and other public institutions which are dependent upon fuel oil. Heating oil supplies the space-heating needs of about one-quarter of such institutions as schools, hospitals, homes for the aged, libraries and other municipal recreation facilities.

Under this program, grants will be available for two project categories: conversion from oil to other fuels, and retrofitting oil-heated buildings with energy-conserving materials and equipment such as insulation

and temperature controls. Our target for this program is to displace at least 20 million gallons of oil annually, for a yearly saving of more than $5-million.

The Ministry of Energy in cooperation with the Ministry of Industry and Tourism are embarking upon a similar program, costing another $10-million over three years, to assist the industrial sector to convert from oil, and to conserve energy. And it is in this sector that the potential savings are even greater, since Ontario industry consumes about 600-million gallons of fuel each year. Working with the Ministry of Industry and Tourism, we have been running, since 1975, our Energy Bus program, to assist industries across Ontario to carry out energy audits and to establish energy management programs. The role of the Energy Bus is also being expanded into other areas.

The Ontario Ministry of Energy in cooperation with the Conservation and Renewable Energy Branch of the Department of Energy Mines and Resources and the Ontario Ministry of Industry and Tourism provides trained staff to assist in initiating an Energy conservation and Management Program.

The mobile support unit, commonly called the Energy Bus, is equipped with a minicomputer and is available to industrial establishments to identify potential energy savings. This program was undertaken by the Ministry of Energy, Ministry of Industry and Tourism and Mohawk College early in 1975 to encourage the province's industry to undertake voluntary energy management programs.

Low-cost electricity and fuels have contributed to Ontario's industrial growth and development. The very abundance of energy resource at low cost in many cases has allowed inefficient use with serious problems or inconveniences.

It is obvious that this situation has ended. Natural gas costs have increased sharply and may go much higher. The same is true for electricity, gasoline, fuel oil and coal. If the demand for electricity continues at its historical growth rate, industry may be faced with brownouts and blackouts.

Of even greater effect may be the upsets and changes in buying energy in alternate forms which will accompany the shortages. As Ontario is Canada's leading industrial province, these changes could have a significant impact on industry and could have a bearing on its industrial competitiveness,

There are no inexpensive and simple solutions. It just makes good sense for small and large companies alike to manage and conserve energy.

Faced with steadily increasing energy costs, product costs can be reduced by using energy more effectively.

The bus with a minicomputer includes a video display, demonstration equipment, and sophisticated energy-measuring equipment. In order to obtain an "on-the-spot" computer analysis of potential dollar savings that will assist in developing efficient management of electricity, natural gas, oil, coal and water, the first step is to find the problem A visit by the Energy Bus is a valuable tool for pinpointing energy wasting practices. This is accomplished in the following manner:

- By analyzing consumption and cost trends and highlighting priorities for potential savings.
- By providing an objective critique of plant energy-usage.
- By alerting top management to the problems of energy effectiveness and to the size of the opportunity.
- By unifying various levels of personnel in the task of energy awareness and effective utilization.

In order to derive maximum benefits it is recommended that top management be represented. Included should be the following key personnel:

- Chief Financial Officer;
- Head of plant engineering and maintenance;
- Manager of production and manufacturing.

Other decision making personnel with plant operating cost responsibilities should also be included. However, as the bus has limited space, only 5 or 6 persons can be accomodated.

Plant visits can be made to companies who have an energy bill of at least $10,000 by contacting your local office of the Ontario Ministry of Industry and Tourism, and obtaining and filling out the confidential audit form and then arranging a date.

The purpose of this audit is to:

1. Permit an "on-the-spot" computer analysis of your energy use and estimate of possible dollar savings.
2. Provides you with an awareness of your firm's energy usages and costs.

This audit form is in two parts. The first is general information about your plant. The second is electrical consumption which can be obtained directly from your local hydro utility. Both parts are necessary for the

audit. The data should be as complete as possible. It should be current and up to the end of the month preceding the bus visit.

The invoices are designed for billing purposes. For example, billed kilowatt (KW) demand may not be the same as your metered kilowatts, depending on your power factor. Your local hydro is your best source of information. By contacting them you will be able to supply us with data including meter multiplier correction and whether or not you pay a transformer metering penalty (1.5%). If it is already included in your data, make a note in the comments. Accurate information into the computer provides accurate output from the computer.

When the bus arrives at your plant:

First, we would like to make a tour through the plant to observe the major points of energy use and your hydro metering. If the latter is in a locked cabinet, arrangements should be made to have it opened in order to take the readings.

Following the tour the ministry consultant meets in the bus conference area with key personnel.

Data from the audit form is fed into the computer and the output displayed on a video screen for a detailed analysis and discussion. Print-outs of the video displays are generated simultaneously and with a summary front page is your "on-the-spot" report of potential dollars savings.

A bus visit usually takes one-half to one full day, depending on the size of the plant. Your local ministry consultant could provide advice on this point.

Typically, a half day visit consists of a two-hour audit - walk-through and measurements, if necessary - followed by about a 1 1/2 hour presentation on the bus. The latter consists of the computer analysis and a discussion. Longer or more complex operations, necessitating a full day's visit, may require up to a three-hour presentation.

The wide ranging programs, involving years of effort and millions of dollars does not represent massive government intervention in the market place; while governments are spending substantial sums; it is expected that the private sector investments in energy conservation will be much greater. For instance, the following statistics are based on the results achieved by Ontario's Energy Bus Program over a four-year operational period.

Number of Energy Bus visits	1048
Total Energy Expenses Surveyed	$360,000,000
Total Potential Savings	$ 44,271,000
Percentage Potential Savings	12.2%
Average Potential Savings	$ 42,150,000

Although some investment in manpower and material is required to implement the potential savings, it has been reported by a number of companies that the majority of these savings can pay for themselves in less than a year. The resulting savings contribute to an improved Company Profit Picture in addition to preserving precious non-renewable energy which will add to our future energy security.

Practicing energy conservation in your industry is indeed a practical and viable alternative to the efficient management of our diminishing energy resources.

ENERGY USE IN THE CANADIAN FOUNDRY INDUSTRY

by

Barry James

Energy, like labour and materials, is a basic production input in the manufacturing processes of the foundry and other primary metals industries. This paper presents the energy use patterns of the industry in terms of the primary energy input types, the quality and form of the energy actually required by the various production processes, and the residual form of this energy, either embodied in the product or rejected in gaseous and liquid waste heat streams. The opportunities, and advantages of implementing energy saving measures to improve the efficiency of energy use, are related to the changing role of energy since the 1973 oil crisis. It appears that energy will be an increasing concern for the industry during the 1980's. Energy savings will lead directly to increased profit for the foundry industry. These savings will also make a highly cost-efficient contribution to the overall national energy strategy.

INTRODUCTION

On a per capita basis, energy consumption in Canada is the second highest in the world, and it continues to grow. By itself, this statistic does not necessarily denote inefficiency of energy use, as it reflects a mix of factors such as energy prices, climate, geography, industrial structure, life-style preferences, etc. It does indicate, however, that Canada is more reliant on energy and presumably more vulnerable to price increases and supply problems.

Following a long period characterized by declining real-energy prices and an abundance and choice of energy supplies, the situation has been changing rapidly since the 1973 oil crisis. It is generally accepted that energy prices will continue to increase rapidly, and that there will be uncertainties about the continuity of supply of some energy types. In

essence, a period of relative stability has been replaced by a period of uncertainty, which will continue through the 1980's.

In such a period, a reassessment of the role of energy as a production input is appropriate, particularly for industries such as the Foundry and other Primary Metals industries, which traditionally have energy costs well above the average for industry in Canada.

The following sections outline some of the effects of the changing energy scene on the industry. These effects are dealt with primarily in terms of energy productivity and energy costs, as in most circumstances, a change in the cost of energy as a production input is the end result of both price and energy supply changes.

ENERGY CONSUMPTION PATTERNS

The basic source of general information on industry is the data derived from the annual census of manufacturing conducted by Statistics Canada. In general these data support the trends which are being reported in the increasing number of specific company case studies and industry reports on the subject of energy use and management.

The Primary Metals industry is dominated by the Iron and Steel Mills and the Smelting and Refining industries, in terms of the value of production output, employment, etc. In terms of the number of establishments, however, the smaller operations of the Iron Foundries, the Ferrous and Non-ferrous Casting companies dominate. For the purposes of this paper, the industry is divided in accordance with the Statistics Canada Standard Industrial Classification (SIC).

1. The consumption of purchased fuel and electricity by the Primary Metals industry for the year 1978 is shown in Tables 1 and 2. The period 1962 to 1978 is shown in Table 3.

   (i) The industry is one of the major industrial consumers of energy. In terms of BTU, Primary Metals accounted for 7 percent of total Canadian energy consumption and about one-fifth of the consumption in manufacturing. Iron and Steel Mills and Smelting and Refining together accounted for over 90 percent of Primary Metals. This relative importance increases considerably if metallurgical coal and self-generated hydro electricity are included.

(ii) The industry is dependent on all the major energy types. Apart from metallurgical coal, whose use has remained relatively constant during the 1970's, natural gas is the dominant fuel. On a percentage basis, natural gas usage doubled between 1962 and 1972 and has further increased to around 40 percent by 1978. The petroleum products share has decreased slightly and electricity increased slightly over this period. In any particular company any one energy type may dominate, depending on the melting processes employed.

(iii) Energy consumption growth rates have changed significantly during the 1970's. Primary Metals grew steadily during the 8-year period 1962-70 at an average annual rate of 6 1/2 percent, followed by almost zero growth during 1970-78. Smelting and Refining grew steadily at 6 percent from 1962 to a peak in 1971, then declining steadily at 3 1/2 percent through to 1978. Others, such as Iron Foundries, also peaked during the early 1970's and have since declined steadily in their energy use.

(iv) Primary Metals industries dependent on oil products and electricity paid considerably more per unit of energy than did industries with access to or the ability to use natural gas. Unit energy costs for Primary Metals, Smelting and Refining, and Iron Foundries are shown in Table 6, in current dollars and in real dollars. Real prices declined through the 1960's but have increased steadily since 1973. Individual energy types have increased in current dollars by 100 to 400 percent during the period 1973-1978. Prices can be expected to double or triple again by 1985. These trends are shown in Fig. 1.

2. The relative costs of energy, wages, and materials and supplies as production inputs are shown for the years 1962, 1972 and 1978 in Table 4.

(i) Primary Metals industries on average spent more than twice as many dollars on energy relative to the other production inputs than the average for manufacturing industries. Iron and Steel Mills, Iron Foundries and Smelting and Refining have particularly high energy input costs. For example, Smelting and Refining

spent 14.4 cents on energy out of energy dollar in 1978, compared to the manufacturing average of 3.5 cents. This is more than half the cost of wages in the industry.

(ii) Energy costs increased considerably, as much as 54 percent in one case, relative to other production input costs in the period 1972-1978. The relative cost of wages has declined sharply, materials and supplies have increased slightly. In other words, energy has rapidly increased its importance as a production cost factor.

3. The energy requirements of the Primary Metals industry are shown in Table 5 in terms of the primary energy input types as purchased by the manufacturing establishment, the form and quality of this energy as actually consumed by the various production equipment and processes, and the residual form of the energy, either embodied in the product or rejected in gaseous and liquid waste heat streams.

(i) Actual energy requirements are considerably different from the primary energy input types. Over 90 percent of the equipment and process requirements are for some form of heat, rather than for oil or gas per se. Furthermore, the requirement is for heat at a much lower temperature than the combustion temperature of the primary energy type.

(ii) There is considerable energy contained in the gaseous and liquid waste heat streams which are rejected via stacks and outlet pipes, and through radiation from building and exposed process surfaces. The energy contained in definable waste heat streams represents 28 percent of the total primary energy inputs. The quantity of heat rejected in the 212°-500°F range is apparently considerably greater than the primary requirement in that range, which suggests the opportunity for waste heat recovery and re-use.

ENERGY PRODUCTIVITY TRENDS

General energy and economic statistics for the period 1962 to 1979 are shown in Table 6. Factors such as unit costs, production output value and production capacity utilization are useful indicators which explain the changing trends in energy consumption patterns.

Energy productivity, expressed as an energy use intensity index (BTU per constant 1971 dollar of production output), has been improving since the

early 1970's following more than a decade of increasing energy intensity. Primary Metals were using, on average, approximately 12 percent less energy per unit of output in 1978 relative to 1972, the "pre-oil crisis" base year. Smelting and Refining became more than 20 percent and Iron Foundries approximately 15 percent less energy intensive respectively, over the same period.

These improvements were achieved during a period of real-price increases in the cost of energy. Somewhat surprisingly, however, they were also achieved during a period of reduced production output and a markedly lower production capacity utilization, circumstances which tend to cause lower efficiency of use of inputs such as energy. Increased energy use is also associated with the improving environmental standards and employee health and safety standards which have been developed over the period. Despite these negative influences, the industry has been able to achieve significant improvements in energy productivity.

The energy consumption and productivity improvements for the total Primary Metals industry are shown in Figure 2 for the period 1962 to 1979.

ENERGY SAVINGS IN THE 1980's

Because of the high energy consumption and the rapidly rising energy costs in Canada, considerable effort is being made by both industry and government to reduce energy waste and thereby improve the efficiency of energy use. In 1975, a government/industry conference on industrial energy conservation led to the formation of a voluntary program of industrial energy conservation Task Forces. Fifteen Task Forces, representing all the major industrial sectors and accounting for approximately 80 percent of the energy used by industry, have set energy efficiency goals for 1980 and 1985, relative to a base year which in most cases is 1972.

Ferrous metals (the iron and steel mills) and Mining and Metallurgy (including smelting and refining) represent the Primary Metals industry. The combined Task Force goal is to improve energy efficiency 12 percent by 1980 and 23 percent by 1985.

All indications are that the Primary Metals industries will achieve further improvement beyond the 12 percent they had achieved by 1978 (see Table 6). Figure 3 shows a reasonable projection, with a 20 percent improvement by 1985, based on the Task Force expectations. The horizontal Historical

(1972) line indicates the energy intensity of the industry if no improvement has been achieved beyond 1972.

The corresponding levels of energy consumption are shown in Fig. 4 with the corresponding energy savings relative to the Historical (1972) situation. The total savings to 1978 amounted to $290 million. If the 1985 improvement level is achieved, a total saving of approximately $2 billion will have been achieved. In the year 1985, the total estimated energy bill will be approximately $1.8 billion, with the savings in that year amounting to $430 million or almost 25 percent. Accumulated savings will be 490 trillion BTU, more than double the consumption in 1978.

These savings will result in increased profits and free up significant amounts of capital for production or market expansion opportunities. Energy savings end up directly as pre-tax profit with a dollar of energy savings being equivalent to 10-20 times the profit from a dollar increase in production output.

Relative to this average Primary Metals situation, Smelting and Refining, and Iron Foundries appear to be making greater progress, and hence the percentage energy savings will be even more impressive. Energy conservation is, of course, an individual choice for each plant and opportunities will obviously differ from plant to plant. Improvements of over 50 percent are proving to be reasonably common as companies analyse and test their situation to the limit.

Energy conservation, through the retrofitting of measures to improve the efficiency of energy use in existing plants, and through careful design in new plants, appears to be in the best interest of industry and the nation as a whole. There are excellent financial returns to industry, while from the national perspective, the cost savings appear to be very competitive compared to the cost of developing new sources of energy supply. From both perspectives, conservation is cost-effective.

It is interesting to consider energy conservation measures as "conservation energy" whereby the energy saved directly offsets the need to produce that amount of energy. Each unit of energy saved is a saving in the marginal cost of supply, and today, with the next increments of energy coming from frontier sources of gas, heavy oil deposits, and costly conversion processes, the marginal cost of energy supply is now well above the average

energy supply cost. Table 7 provides a comparison of the costs of saving energy and the costs of new supply.

In summary, it will be factors such as energy prices and availability, the state of the economy, the development of new equipment and processes, and most importantly, the engineering and management decisions at the company level, which will determine exactly which energy consumption and cost path that the Foundry and other Primary Metals industries follow during the 1980's.

Table 1. Consumption of purchased fuel and electricity in 1978.

NATURAL UNITS (in thousands)	Coal & coke (short tons)	Gasoline (Can. gallons)	Kerosene (Can. gallons)	Diesel fuel oil (Can. gallons)	Light fuel oil (Can. gallons)	Heavy fuel oil (Can. gallons)	Liquified petroleum (Can. gallons)	Natural gas (cu.ft.)	Electricity (mwh)	Other	TOTAL Energy
TOTAL MANUFACTURING	1,616	137,747	20,041	103,335	159,443	1,677,259	76,705	529,997	85,517		
TOTAL PRIMARY METALS	392	4,094	2,491	8,800	26,402	286,380	9,304	90,621	17,257		
Iron & Steel Mills	-	1,473	310	5,342	4,907	150,365	2,518	57,417	7,577		
Steel Pipe & Tube Mills	-	66	30	107	81	692	90	3,373	493		
Iron Foundries	8	305	934	231	994	428	839	2,191	446		
Smelting & Refining	377	1,333	962	2,208	10,977	129,894	2,920	22,816	8,804		
Aluminum Rolling, Cast., Ext.	-	208	-	224	6,319	3,410	1,980	1,737	321		
Copper Rolling, Cast., Ext.	-	63	191	224	697	1,186	236	1,106	221		
Misc. Metal Roll., Cast., Ext.	10	647	64	610	2,427	406	721	1,981	114		
DOLLAR COST (in thousands)											
TOTAL MANUFACTURING	71,501	116,624	10,714	70,986	75,255	595,964	37,235	930,375	1,305,525	167,988	3,384,167
TOTAL PRIMARY METALS	30,951	3,102	1,382	4,901	11,708	103,960	4,550	167,969	226,313	8,159	562,995
Iron & Steel Mills	-	1,027	183	2,708	2,100	54,986	1,176	116,537	111,636	6,690	297,043
Steel Pipe & Tube Mills	-	55	16	59	33	256	55	5,591	7,495	-	13,560
Iron Foundries	304	256	475	168	443	152	463	4,163	10,661	1,260	18,345
Smelting & Refining	30,333	1,001	555	1,415	5,004	46,694	1,396	31,555	83,997	80	202,030
Aluminum Roll., Cast., Ext.	-	180	-	123	2,748	1,263	942	3,816	5,484	-	14,556
Copper Rolling, Cast., Ext.	314	527	40	373	1,017	178	398	3,998	2,535	25	9,405

Source: Statistics Canada Catalogue 57-208

Table 2. Consumption of purchased fuel and electricity in 1978.

	Coal & coke	Gasoline	Kerosene	Diesel fuel oil	Light fuel oil	Heavy fuel oil	Liquified petroleum	Natural gas	Electricity	Other[a]	TOTAL Energy
BTU (in trillions)											
TOTAL MANUFACTURING	39.74	20.55	3.25	17.21	26.55	301.30	8.97	530.00	291.78		1,239.35
TOTAL PRIMARY METALS	9.93	0.61	0.40	1.47	4.40	51.40	1.09	90.62	58.88	(325)	218.80
Iron & Steel Mills	-	0.22	0.05	0.89	0.82	27.01	0.29	57.42	25.85	(240)	112.55
Steel Pipe & Tube Mills	-	0.01	0.00	0.02	0.01	0.12	0.01	3.37	1.68		5.22
Iron Foundries	0.19	0.05	0.15	0.04	0.17	0.08	0.10	2.19	1.52		4.49
Smelting & Refining	9.55	0.20	0.16	0.37	1.83	23.33	0.34	22.82	27.58	(85)	86.18
Aluminum Rolling, Cast., Ext.	-	0.03	-	0.04	1.05	0.61	0.23	1.74	1.10		4.80
Copper Rolling, Cast., Ext.	-	0.01	0.03	0.01	0.12	0.21	0.03	1.11	0.75		2.27
Misc. Metal Roll. Cast., Ext.	0.24	0.10	0.01	0.10	0.40	0.07	0.08	1.98	0.39		3.37
% OF TOTAL ENERGY BY ENERGY TYPE											
TOTAL MANUFACTURING	3.2	1.7	0.3	1.4	2.1	24.3	0.7	42.8	23.5		100.0
TOTAL PRIMARY METALS	4.5	0.3	0.2	0.7	2.0	23.5	0.5	41.4	26.9		100.0
Iron & Steel Mills	-	0.2	0.0	0.8	0.7	24.0	0.3	51.0	23.0		100.0
Steel Pipe & Tube Mills	-	0.2	0.0	0.4	0.2	2.3	0.2	64.3	32.1		100.0
Iron Foundries	4.2	1.1	3.3	0.9	3.8	1.8	2.2	48.8	33.9		100.0
Smelting & Refining	11.1	0.2	0.2	0.4	2.1	27.1	0.4	26.5	32.0		100.0
Aluminum Roll., Cast., Ext.	-	0.6	-	0.8	21.9	12.7	4.8	36.2	22.9		100.0
Copper Rolling, Cast., Ext.	-	0.4	1.3	0.4	5.3	9.3	1.3	48.9	33.0		100.0
Misc. Metal Roll., Cast., Ext.	7.1	3.0	0.3	3.0	11.9	2.1	2.4	58.8	11.6		100.0

Note:[a] Significant quantities of energy are not reported by Statistics Canada as "purchased fuel and electricity". Based on EMR studies, the quantity for 1978 is estimated to be 325 trillion BTU for total Primary Metal industries, 240 trillion BTU's in the Iron and Steel mills category (primarily metallurgical coal) and 85 trillion BTU in the Smelting and Refining category (primarily self-generated hydro electricity). The dollar values shown in Table 1 in the "other" category only represent a small fraction of these total additional quantities.

Base: Based on Statistics Canada Catalogue 57-208.

Table 3. Consumption of purchased fuel and electricity, 1962-1978.

BTU in (trillions)	1962	1970	1971	1972	1973	1974	1975	1976	1977	1978
TOTAL PRIMARY METAL INDUSTRIES										
Coal & coke	29.00	31.34	30.45	27.04	20.12	11.69	10.36	10.02	9.06	9.93
Petroleum products	40.53	58.86	60.02	55.53	49.41	57.43	48.45	47.64	58.69	59.37
Natural gas	22.92	56.36	62.39	68.21	77.62	83.67	87.17	77.68	81.10	90.62
Electricity	28.31	53.98	51.28	53.49	56.58	60.48	56.45	56.29	52.38	58.88
Total energy	120.76	200.54	204.14	204.27	203.73	213.27	202.43	191.63	201.23	218.80
Smelting and Refining										
Coal & coke	25.19	28.52	28.07	25.98	19.78	10.86	9.71	9.52	8.75	9.55
Petroleum	10.68	24.16	28.34	25.94	24.29	30.62	26.06	25.75	31.11	26.23
Natural gas	12.12	21.34	22.83	22.12	26.32	26.42	26.86	21.65	21.19	22.82
Electricity	17.22	28.51	30.19	30.22	32.09	33.39	32.12	31.79	24.80	27.58
Total energy	65.21	102.53	109.43	104.26	102.48	101.29	94.75	88.71	85.85	86.18
Iron Foundries										
Coal & coke	0.89	0.69	0.56	0.53	0.27	0.65	0.45	0.32	0.11	0.19
Petroleum products	0.72	0.77	0.76	0.80	1.00	0.93	0.93	0.66	0.65	0.59
Natural gas	0.30	1.57	1.49	1.68	2.07	2.13	1.95	2.16	2.01	2.19
Electricity	0.26	0.92	1.02	1.19	1.30	1.52	1.38	1.41	1.48	1.52
Total energy	2.17	3.95	3.83	4.20	4.64	5.23	4.71	4.55	4.25	4.49

Source: Based on Statistics Canada Catalogue 57-208 and 57-506.

Table 4. Relative production costs.

Costs as a % of total production costs

	Cost of fuel and electricity			Cost of wages			Cost of material and supplies		
	1962	1972	1978	1962	1972	1978	1962	1972	1978
TOTAL MANUFACTURING	2.9	2.6	3.5	20.9	21.4	18.6	76.2	76.0	77.8
TOTAL PRIMARY METALS	5.9	6.1	7.7	24.1	25.4	21.0	70.0	68.5	71.3
Iron & Steel Mills	5.4	5.4	8.2	28.1	27.0	21.5	66.5	67.5	70.2
Steel Pipe & Tube Mills	3.0	1.9	2.5	15.6	16.9	16.6	81.4	81.2	80.9
Iron Foundries	3.2	4.4	5.3	38.3	40.6	37.1	58.4	55.0	57.6
Smelting & Refining	10.3	13.4	14.4	25.6	31.9	27.0	64.1	54.6	58.6
Aluminum Roll., Cast., Ext.	2.0	2.0	2.0	14.6	16.4	10.1	83.4	81.6	87.9
Copper Roll., Cast., Ext.	1.3	1.3	2.0	10.5	10.8	11.4	88.2	88.0	86.6
Other	2.1	2.4	2.9	13.4	17.7	15.7	84.5	79.9	81.4

% Change in costs

	1962-1972			1972-1978		
	Fuel and electricity	Wages	Materials and supplies	Fuel and electricity	Wages	Materials and supplies
TOTAL MANUFACTURING	-10	2	0	35	-13	2
TOTAL PRIMARY	3	5	-2	26	-17	4
Iron & Steel Mills	0	-4	2	52	-20	4
Steel Pipe & Tube Mills	-37	8	0	32	-2	0
Iron Foundries	38	6	-6	20	-8	5
Smelting & Refining	30	21	-15	7	-13	7
Aluminum Roll., Cast., Ext.	0	12	-2	0	-38	8
Copper Roll, Cast., Ext.	0	3	0	54	6	-2
Other	14	32	-5	17	-11	2

Source: Based on Statistics Canada Catalogue 31-203.

Table 5. Energy use patterns, 1978

(BTU in trillions)

TOTAL PRIMARY INDUSTRIES

ENERGY INPUTS BY TYPE

Coal & coke	10
Gasoline	1
Fuel oils	58
Liq. pet. gas	1
Natural gas	91
Electricity	59
Other[a]	325
TOTAL	545

→

ENERGY INPUTS BY FORM AND QUALITY

Non-heat energy		49
Heat energy:		
Electricity as heat	115	
Process heat >500°F	344	
Process heat 212°F-500°F	36	
Process heat <212°F	-	
		495
TOTAL		544

→

ENERGY IN RESIDUAL FORM

Non-heat energy		49
Radiated Heat		45
Process, product & heating losses		228
Definable rejected energy:		
500°F-1500°F	18	
212°F-500°F	142	
120°F-212°F	10	
<120°F	51	
		221
TOTAL		543

(BTU in trillions)

Total energy input	544	
Definable rejected energy	221	... 41% of total energy input
Theoretical recoverable energy	161	... 73% of definable rejected energy
Practical recoverable energy	62	... 28% of definable rejected energy
		(36% in the case of smelting and refining)
		(28% in the case of rolling, casting and extruding)

Note: [a] "Other" includes metallurgical coal and self-generated hydro electricity.

Source: Based on an EMR study of energy cascading potential in Canada.

Table 6. Energy and economic profiles, 1962-1979.

TOTAL PRIMARY METAL INDUSTRIES	1962	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Energy consumption (BTU in trillions)	120.76	200.55	204.14	204.28	203.74	213.27	202.42	191.62	201.23	218.85	
Energy cost ($'s in thousands)	88,718	170,690	183,414	186,300	211,896	276,035	317,595	375,938	462,746	562,997	
Unit energy cost ($'s per million BTU)	0.73	0.85	0.90	0.91	1.04	1.29	1.57	1.96	2.30	2.57	
(1971 $'s per million BTU)	1.00	0.88	0.90	0.87	0.91	0.98	1.07	1.22	1.34	1.41	
Production output value (1971 RDP $'s in millions)	1,046.4	1,653.0	1,637.5	1,665.3	1,853.0	2,008.2	1,799.5	1,763.3	1,901.1	2,024.9	2,040.0
Production capacity utilization (%)	82.8	92.7	87.5	85.4	91.5	95.1	81.1	76.3	80.0	83.1	82.1
Energy use intensity (BTU per 1971 RDP $)	115,405	121,325	124,666	122,669	109,951	106,200	112,487	108,671	105,849	108,079	
Intensity index (1972=100)	94.1	98.9	101.6	100.0	89.6	86.6	91.7	88.6	86.3	88.1	
SMELTING AND REFINING											
Energy consumption (BTU in trillions)	65.20	102.53	109.42	104.27	102.39	101.28	94.74	88.70	85.85	86.18	
Energy cost ($ in thousands)	46,697	88,630	95,280	88,289	99,507	118,404	141,134	156,870	179,016	202,031	
Unit energy cost ($'s per million BTU)	0.72	0.86	0.87	0.85	0.97	1.17	1.49	1.77	2.09	2.34	
(1971 $'s per million BTU)	0.98	0.89	0.87	0.81	0.85	0.88	1.02	1.10	1.21	1.28	
Production output value (1971 RDP $'s in millions)	343.9	498.6	509.6	479.5	495.8	529.5	495.8	441.8	541.2	514.2	458.1
Production capacity utilization (%)	82.8	92.7	87.5	85.4	91.5	95.1	81.1	76.3	80.0	83.1	82.1
Energy use intensity (BTU per 1971 RDP $)	189,590	205,636	214,737	217,456	206,535	191,257	191,085	200,770	158,610	167,600	
Intensity index (1972=100)	87.2	94.6	98.6	100.0	95.0	88.0	87.9	92.3	72.9	77.1	
IRON FOUNDRIES											
Energy consumption (BTU in trillions)	2.17	3.95	3.83	4.24	4.64	5.24	4.71	4.55	4.24	4.49	
Energy cost ($'s in thousands)	2,545	6,107	6,688	7,469	8,552	11,127	12,039	14,085	16,984	18,344	
Unit energy cost ($'s per million BTU)	1.17	1.55	1.75	1.76	1.84	2.12	2.56	3.10	4.01	4.09	
(1971 $'s per million BTU)	1.60	1.60	1.75	1.68	1.81	1.81	1.75	1.93	2.33	2.24	
Production output value (1971 RDP $'s in millions)	82.3	118.8	114.4	122.9	140.5	164.7	143.7	140.8	136.5	152.2	143.2
Production capacity utilization (%)											
Energy use intensity (BTU per 1971 RDP $)	26,367	33,249	33,479	34,500	33,025	31,815	32,777	32,315	31,062	29,501	
Intensity index (1972x100)	76.4	96.4	97.0	100.0	95.7	92.2	95.0	93.7	90.0	85.5	

Sources: Energy - Statistics Canada Catalogues 57-208 and 57-506
Production output value - Statistics Canada Catalogues 61-005 and 61-213
Production capacity utilization - based on Statistics Canada, Bank of Canada and Industry, Trade and Commerce Canada published data.

Table 7. Comparative costs of conservation and new energy supply projects. (1978 $/million BTU)

Industrial retrofit	- insulation) - controls) - heat recovery) - process change)	$ 0 - 3.50
Transportation	- van pooling	$ 2.10
Residential retrofit	- oil furnace	$ 0.60 - 1.20
	- insulation	$ 1.00 - 3.40
Supply prices	- frontier natural gas	$ 2.30 - 2.90
	- oil sands project	$ 4.10 - 5.00
	- oil imports	$ 4.50
	- nuclear electric power	$ 5.50 - 6.80

FIGURE CAPTIONS

Fig. 1. Energy commodity prior Canadian averages.

Fig. 2. Consumption and productivity trends. Primary metals.

Fig. 3. Productivity trend 1962-1985. Primary metals.

Fig. 4. Consumption and savings 1962-1985. Primary metals.

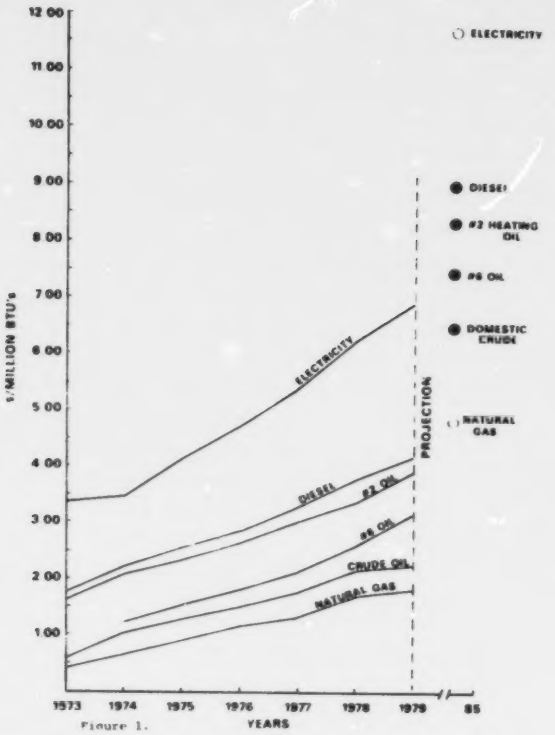


Fig. 1. Energy commodity prior Canadian averages. (neg 5022)

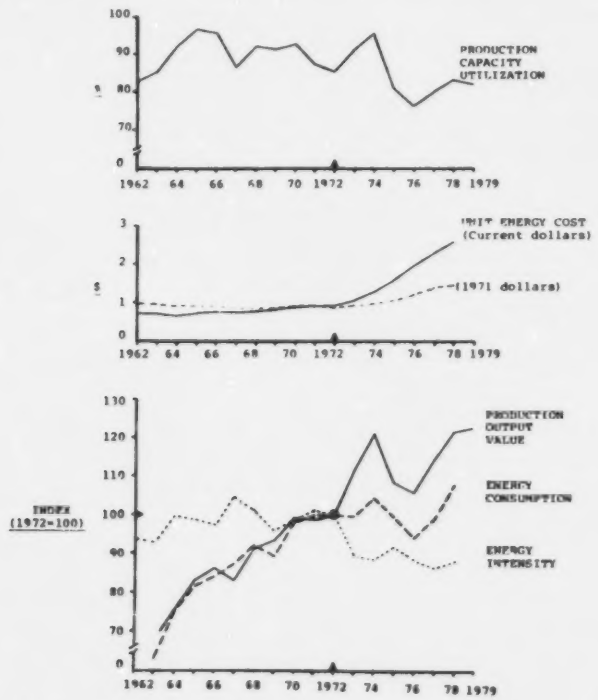


Fig. 2. Consumption and productivity trends. Primary metals. (neg 5021)

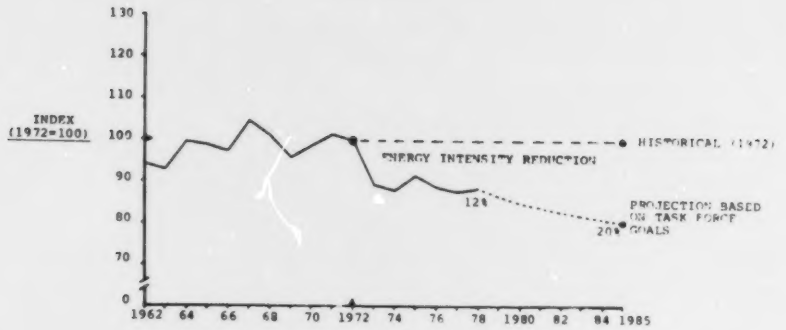


Figure 3.

Fig. 3. Productivity trend 1962-1985. Primary metals. (neg 5019)

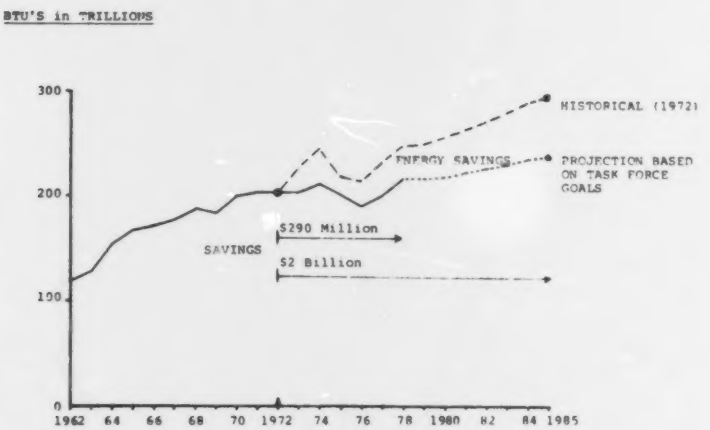


Figure 4.

Fig. 4. Consumption and savings 1962-1985. Primary metals. (neg 5020)

EFFICIENT LADLE PREHEATING

by

K.G. Davis and J.G. Magny

ABSTRACT

We have examined the efficiency of preheating a 1000 lb (450 kg) ladle by a natural gas torch, with respect to torch-head position, ladle configuration, lining material and thickness, and the use of ladle covers. We obtained the highest preheat temperatures in an open ladle with the torch-head near the centre of the ladle mouth, approximately level with the rim. There was no advantage in having the ladle on its side or inverted, compared with the normal, upright position. A fireclay-mullite refractory lining reached a higher temperature after a given preheat than did a high-alumina lining. With an insulating cover, we obtained a 50% saving of gas to reach a given lining temperature.

INTRODUCTION

The not uncommon sight of a gas- or oil-fired torch pouring much of its heat into the surrounding air provides one of the most visible areas in a foundry operation where energy is wasted. As part of PMRL's program on "Energy Conservation in the Metal Casting Industry", we did not look at torch design itself, nor at the relative merits of heating ladles with gas, oil, or electricity. Rather, our objective has been to determine the most efficient way to operate existing gas- or oil-fired torches. The variables studied were:

(1) Torch position. Should the torch-head be level with the ladle rim, above, or below it? Should it be central, or off to one side?

(2) Ladle position. Should the ladle be on the floor open-end up, or on its side, or inverted?

(3) Linings. Are some types of ladle lining refractory superior to others with respect to heating, and what is the best thickness?

(4) Covers. Should ladles be covered during preheating, and if so what is the best design for the cover?

We expected answers to such questions to be readily available in published reports, but this is not so. In the few cases where the effect of this type of variable on preheat efficiency has been investigated, several parameters were often changed simultaneously, to upgrade an operation. The effect of each variable is then difficult to judge.

TECHNIQUE

We performed tests on the PMRL foundry's largest ladle, designed to hold up to 1000 lb (450 kg) of metal. Two types of rammed refractory lining were used. One had 2/3 fireclay and 1/3 mullite, and had an alumina content of about 45%. The other was a high-alumina type containing 95% alumina. Lining thickness was either 4 in. (100 mm) or 2 in. (50 mm). We drilled $\frac{1}{4}$-in. (6.4-mm) diameter holes through the ladle shell and lining, at positions shown in Fig. 1, and cemented thin-walled silica tubes, closed at one end, into the holes. The closed end was made flush with the inner lining surface. We inserted Pt-Pt 13% Rh thermocouples of 20-mil (0.52-mm) wire into the tubes, and recorded the output on a datalogger at regular intervals. The ladle and

measuring system are shown in Fig. 2. In early tests we installed one thermocouple only at each of positions 2, 3, 4, whereas in later ones we installed three tubes symetrically around the ladle at position 3.

We used two methods to obtain temperature profiles through the linings. In one, we moved a thermocouple along its silica tube, and measured the temperature at various positions. This will be referred to as a traverse. Traverses work only when the heating or cooling rates are low. In the other method, we used a probe consisting of a bundle of four thermocouples with their junctions at fixed distances apart, cemented into one of the holes in the ladle lining.

The first tests showed clearly that even with the torch central in the ladle mouth, the flame was always offset, so heating was not uniform. The following sections give average values for the three side-middle thermocouples, to compensate for non-uniformity in the heating.

As a first step, we determined the scatter in data from tests made with the same gas flow rate and torch position (Fig. 3). The range in measured temperature at the same ladle position was about 100°C (180°F), showing that multiple tests were needed for each set of heating conditions if variations of this order were to be measured.

OPEN LADLE

Torch Head Position. The effect of torch head height in the mouth of an open ladle is shown in Fig. 4. Raising the torch-head some 5 in. (130 mm) caused a small reduction in preheat temperature, and raising it a further 4 in. (100 mm) resulted in a larger drop. Lowering the torch head below the ladle rim gave excessive heating of the torch with no advantage in heating rate. A position approximately level with the rim appears to be optimum. Moving the torch laterally from its central position had no effect, except that with the torch head near the ladle wall we obtained poor heating unless the head was tilted slightly away from the wall (Fig. 5).

Ladle Position. An inverted ladle was marginally superior to an upright one (Fig. 6). The advantage was not, however, sufficient to justify the adoption of an inverted position. With the ladle on its side, and the torch central in the ladle mouth, there was again no significant advantage over the upright

position. A torch head position near the top or bottom of the ladle mouth gave lower lining temperatures (Fig. 7.).

Lining Material. The influence of the type of lining refractory is demonstrated in Fig. 8, which shows results both for the fireclay-mullite mix and the high-alumina refractories. The high-alumina refractory gave lining temperatures some 100°C (180°F) lower.

COVERED LADLE

In Fig. 9, heating curves for an open ladle are shown with those for a ladle with a cover made of 2-in. (50-mm) of ceramic-fibre insulation glued onto a flat steel plate. We provided three 2-in. (50-mm) vent-holes for exhaust gases, placed symetrically around the torch head, which was at the centre of the cover. A large increase in lining temperature, about 300°C (540°F), was achieved. The same heating curve can be obtained with an open ladle at the full gas flow rate or a covered ladle at about half that flow rate (compare Figs. 9, 10), which means that for a given preheat about 50% less gas is needed with a covered ladle. Conical covers, and covers with rammed refractory instead of ceramic fibre insulation, gave similar results.

TEMPERATURE PROFILES THROUGH THE LINING

Lining surface temperatures only have been considered to this point. We shall now consider temperature profiles through the linings. A typical example is shown in Fig. 11. Temperature is approximately linear with distance from the inner lining surface, dropping to about 500°C (930°F) after 2 in. (50 mm). These are common features for all the tests, including those on covered ladles and those on ladles with the thinner (2 in., 50 mm) linings.

Cooling rates after the torch was turned off are shown in Figs. 12, 13. The surface temperature dropped rapidly in the first two minutes, about 120°C (216°F) in the open ladle and 80°C (144°F) in the covered ladle. These large temperature drops emphasize the importance of keeping the interval between torch shut-off and tapping into the ladle as short as possible.

The temperature distribution after filling with iron at approximately 1600°C (2880°F) to simulate steel practice, is shown in Fig. 14. The ladle had a 2 in. (50 mm) lining of high-alumina refractory.

Temperature in the lining near the shell remained constant for the first 6 minutes after tap, and had risen by less than 100°C (180°F) after 15 minutes. These factors were the same for the thicker high-alumina linings, and for both thicknesses of the fireclay-mullite linings.

THE EFFECT OF PREHEAT ON METAL TEMPERATURE IN THE LADLE

The temperature reached by a ladle lining during preheating is significant only in terms of the effect on metal temperature in the ladle. We can estimate the expected drop in metal temperature caused by heat transferred to the lining as follows. Figure 15 shows idealized temperature profiles through the ladle lining, both after two preheats, and after metal has been tapped into the ladle. We can readily calculate the difference in heat transferred from the metal to the lining between the poor preheat (b) and the superior preheat (a) from the shaded area in the diagram. The superior preheat will give an advantage in metal temperature of about 11°C (20°F) for the fireclay-mullite lining, and 19°C (34°F) for the high-alumina lining. These figures will remain approximately the same whether the ladle is filled with cast iron or steel.

On a similar basis, we have calculated the temperature drop caused by heat-transfer from the metal to the ladle lining in cold and preheated ladles of various sizes. The results are shown below. Even with big ladles, preheating is seen to be an important factor in determining the superheat needed in the furnace to allow a desirable pour temperature.

TEMPERATURE DROP (ΔT) CAUSED BY HEAT-TRANSFER FROM MOLTEN STEEL OR CAST IRON TO A LADLE LINING

Ladle diameter		Weight of metal		ΔT with 900°C (1650°F) preheat				ΔT with no preheat			
				fireclay		alumina		fireclay		alumina	
in.	cm	lb	kg	°C	°F	°C	°F	°C	°F	°C	°F
17	43	720	327	48	86	80	144	168	312	280	504
30	76	4,000	1,816	27	49	45	81	95	171	158	284
50	127	18,600	8,444	16	29	27	49	57	103	95	171
70	179	50,000	22,700	12	22	20	36	40	72	67	121

CONCLUSIONS

The main conclusions from this work are:

Open Ladle

(a) With an upright ladle, the best torch-head position is approximately central and level with the ladle rim.

(b) Ladle configuration is not critical. With the ladle horizontal, it is important to keep the torch head central in the ladle mouth.

Covered Ladle

(a) A covered ladle can reach the same lining temperature as an open ladle with about half the gas.

(b) Ladle configuration is immaterial.

(c) The same advantages are obtained whether the cover be flat or conical, and lined with rammed refractory or ceramic-fibre batting.

Lining Material

The high-alumina refractory always required more gas for a given lining temperature than the fireclay-mullite refractory.

Lining Thickness

For holding times up to 15 minutes, only the first 2 in. (50 mm) or so of the lining takes part in heat transfer with the metal.

APPLICABILITY OF THE CURRENT RESULTS TO OTHER LADLES AND HEATERS

The validity of the conclusions reached from the current tests, when extended to industrial practice, must ultimately be demonstrated experimentally. However, certain reasonable assumptions can be made. Even for much larger ladles with far thicker linings, temperature distributions through the linings should be similar to those found here, as the first 2 in. (50 mm) or so only are important in heat-exchange processes. It is also unlikely that the type of burner will affect the main conclusions. On the other hand, the response of a larger ladle to ladle-configuration may be different. There could, for instance, be more significant advantages in inverting a deeper ladle. Also, covers on ladles such as those used for magnesium treatment of

cast iron, which are tall and thin, will probably show less advantage. Finally, with a teapot ladle there may be advantages to preheating in a horizontal position with the spout up, so that most of the gas exhausts through the spout.

RECOMMENDATIONS

The following recommendations for the use of ladle preheating torches can be made. Use an upright ladle with a refractory-lined cover. When it is inconvenient to use a cover, keep the torch-head near the centre of the ladle mouth, level with the rim. Keep the time between torch shut-off and teeming into the ladle as short as possible. A lining thickness over 2 in. (50 mm) had no effect on preheating, so use the minimum thickness compatible with safety and wear requirements. If, however, your holding times are of 15 minutes or over, a thick lining may be needed to prevent overheating the shell. Finally, when selecting the refractory for the ladle lining, consider the savings in fuel and/or the better preheat obtainable with fireclay-mullite refractories compared with high-alumina types, along with other factors such as wear resistance, refractoriness, and ease of knock-out.

ACKNOWLEDGEMENTS

We are indebted to R.K. Buhr, Head, Foundry Section, PMRL, for support and guidance throughout the project. We are also grateful to J.D. Perry, Manager, Laboratory and Quality Control, Canadian Refractories Division, Dresser Industries Canada Ltd., for supplying us with thermal data on our lining refractories.

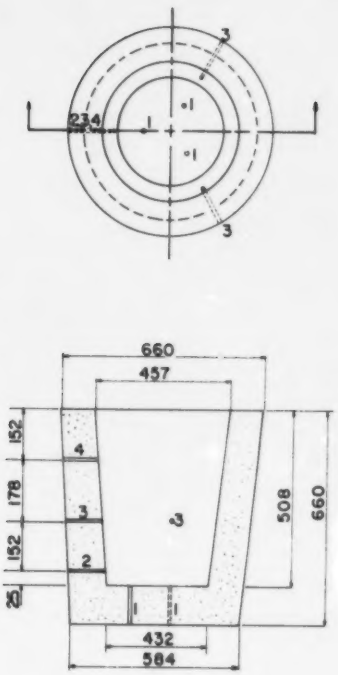


Fig. 1. Ladle dimensions, in millimetres. Also shown are thermocouple positions 1, 2, 3, & 4, termed bottom, side-base, side-middle, and side-top. (neg 3708)

Fig. 2. Test equipment showing the ladle on the floor, with a conical cover. The datalogger is seen on the left. (neg 3289)

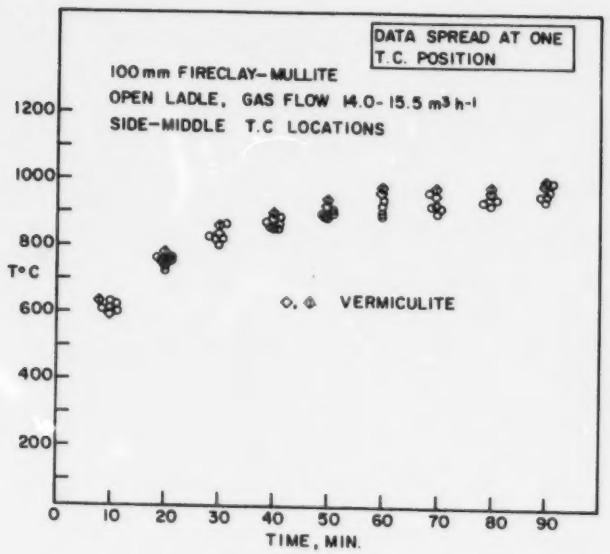


Fig. 3. Data spread for side-middle thermocouples, taken from seven individual tests. Temperatures with symbols ◇ and ◈ are from tests where the ladle shell was encased in vermiculite insulation. Open ladle, 100-mm fireclay-mullite lining. (neg 3726)

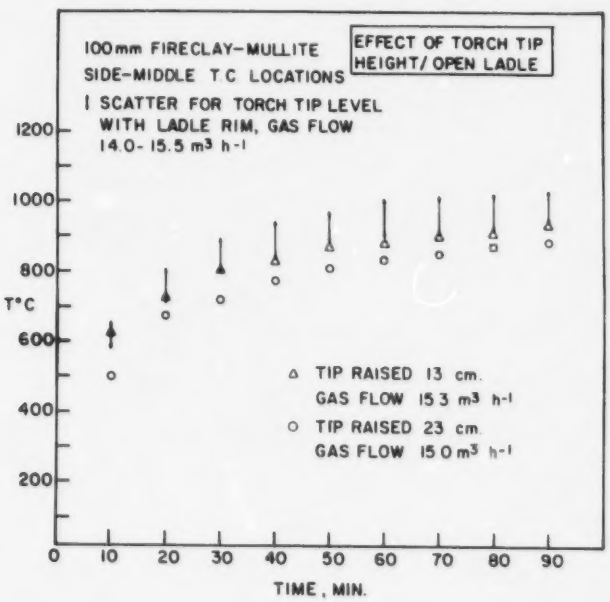

100 mm FIRECLAY-MULLITE
SIDE-MIDDLE T.C LOCATIONS
EFFECT OF TORCH TIP HEIGHT/ OPEN LADLE
I SCATTER FOR TORCH TIP LEVEL WITH LADLE RIM, GAS FLOW 14.0-15.5 m³ h⁻¹
△ TIP RAISED 13 cm. GAS FLOW 15.3 m³ h⁻¹
○ TIP RAISED 23 cm. GAS FLOW 15.0 m³ h⁻¹
T°C
1200
1000
800
600
400
200
0 10 20 30 40 50 60 70 80 90
TIME, MIN.

Fig. 4. The effect of torch height on lining temperature. Open ladle, 100-mm fireclay-mullite lining. Side-middle thermocouple. (neg 4077)

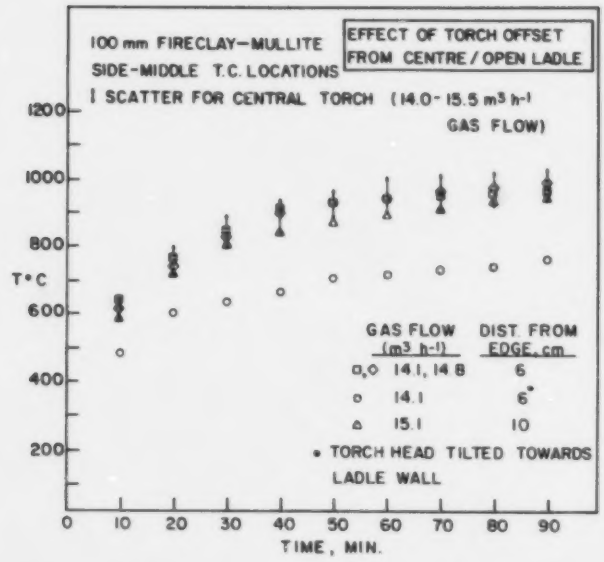


Fig. 5. Effect of torch-head offset in the ladle mouth. Open ladle, 100-mm fireclay-mullite lining. Side-middle thermocouple. (neg 3722)

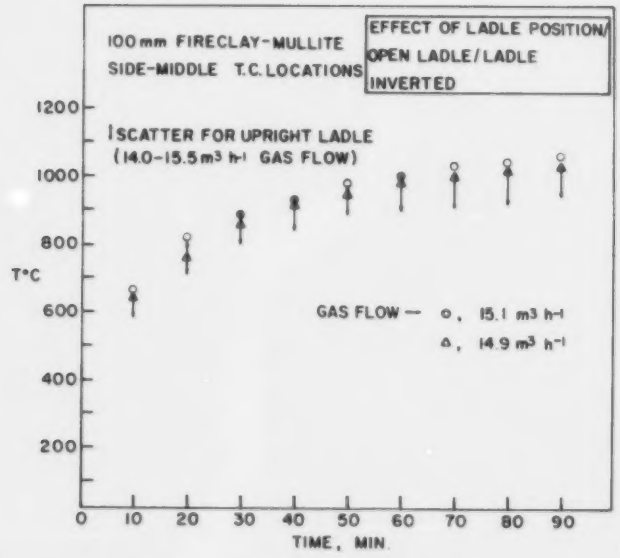

100 mm FIRECLAY–MULLITE
SIDE-MIDDLE T.C. LOCATIONS
EFFECT OF LADLE POSITION/ OPEN LADLE/LADLE INVERTED
I SCATTER FOR UPRIGHT LADLE (14.0–15.5 m³ h⁻¹ GAS FLOW)
T°C
TIME, MIN.
GAS FLOW — ○, 15.1 m³ h⁻¹
△, 14.9 m³ h⁻¹

Fig. 6. Effect of ladle position. Ladle inverted. Open ladle, 100-mm fireclay-mullite lining. Side-middle thermocouple. (neg 3730)

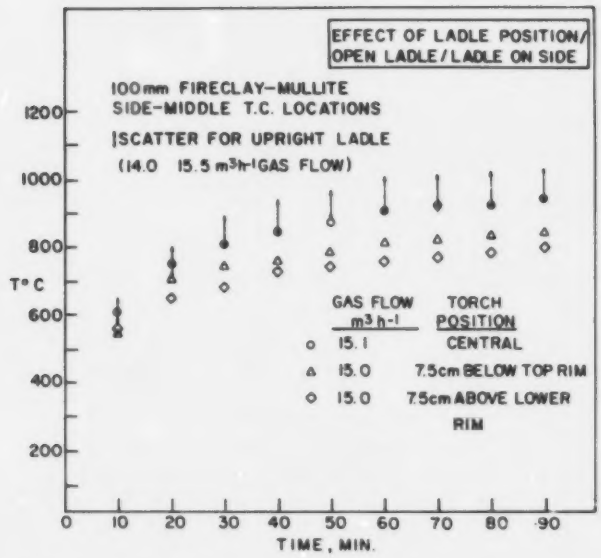


Fig. 7. Effect of ladle position. Ladle on its side. Open ladle, 100-mm fireclay-mullite lining. Side-middle thermocouple. (neg 3727)

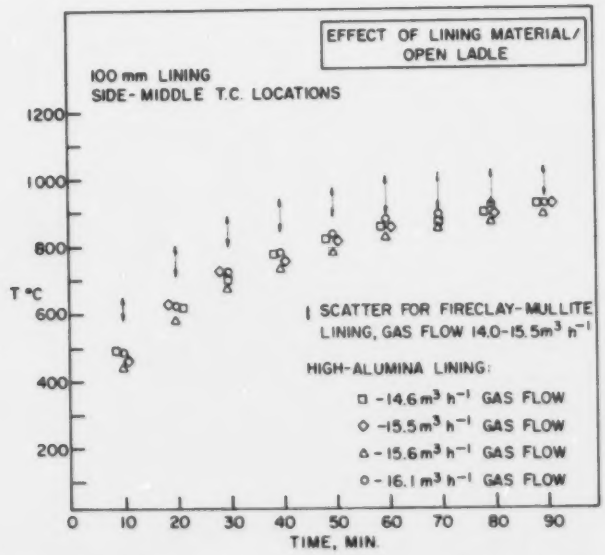


Fig. 8. Effect of lining material. Open ladle, 100-mm lining. Side-middle thermocouples. (neg 3710)

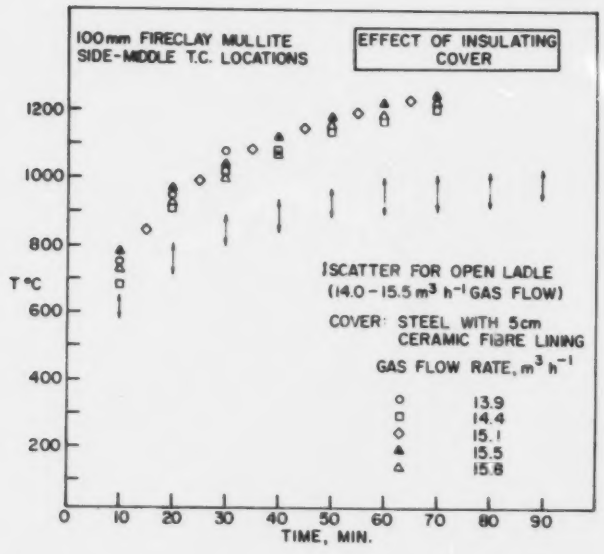


Fig. 9. Effect of insulating cover. 100-mm fireclay-mullite lining. Side-middle thermocouple. (neg 3716)

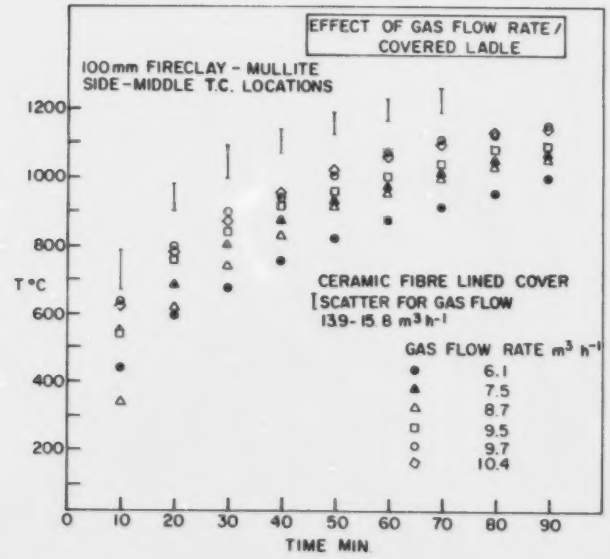


Fig. 10. Effect of gas flow rate. Covered ladle. 100-mm fireclay-mullite lining. Side-middle thermocouple. (neg 3723)

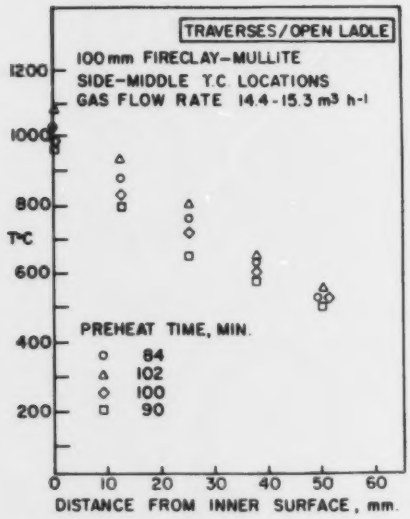


Fig. 11. Temperature traverses through the lining after preheat, for four tests. 100-mm fireclay-mullite lining. Side-middle thermocouple. (neg 4084)

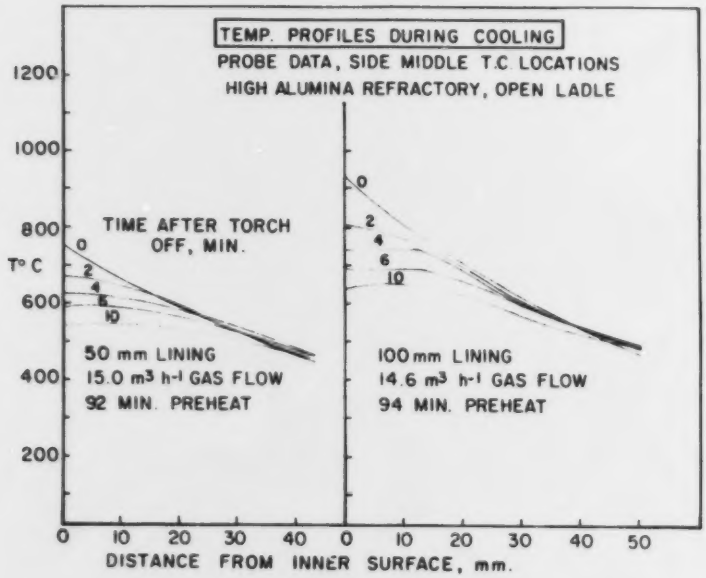


Fig. 12. Temperature profiles through the lining after torch shut-off. Open ladle. Probe data. High-alumina lining. Side-middle. (neg 4074)

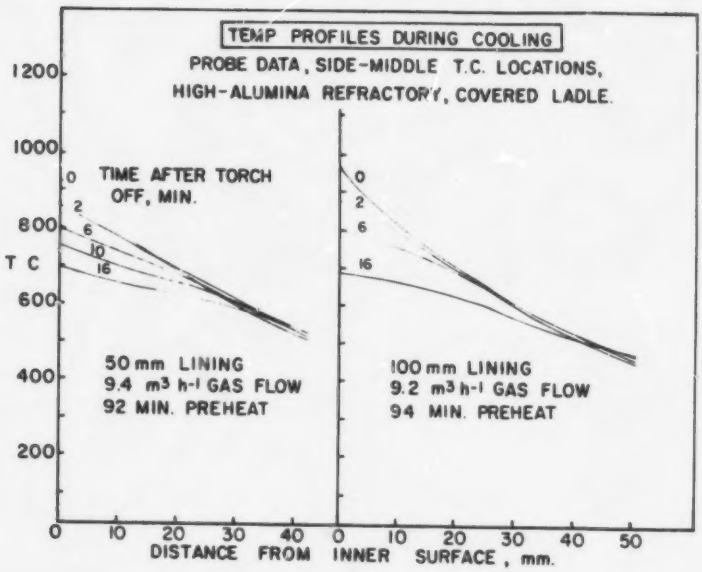


Fig. 13. Temperature profiles through the lining after torch shut-off. Open ladles, high-alumina linings. Probe data. Side-middle position. (neg 4076)

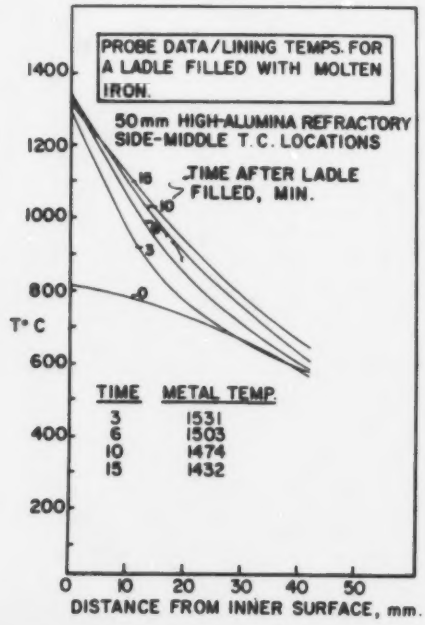


Fig. 14. Temperature profiles through the lining for a ladle filled with molten cast iron. Probe data. 50-mm high-alumina lining. Side-middle position. (neg 4072)

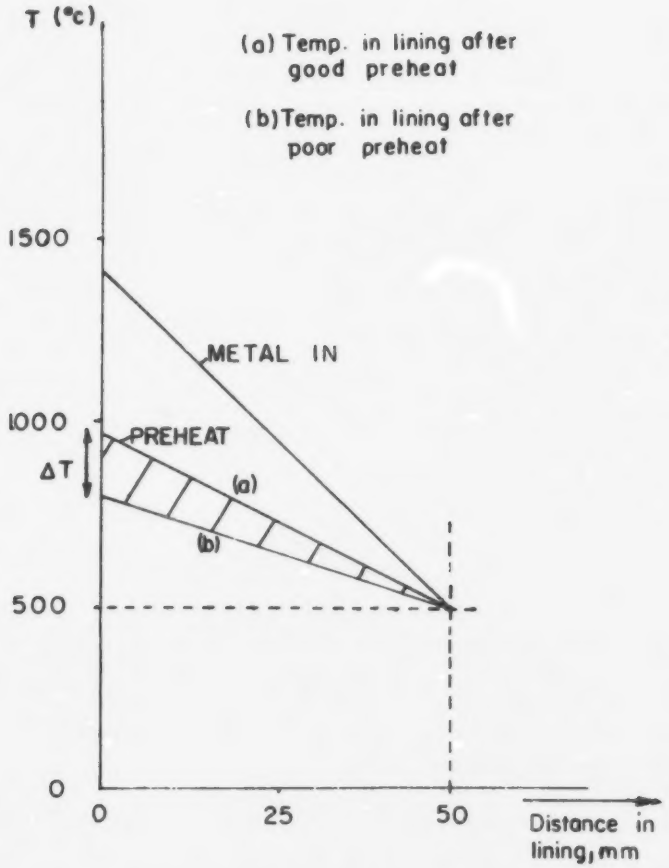


Fig. 15. Idealized temperature distributions after a good preheat (a) and a poor preheat (b). Also shown is the profile t minutes after the ladle has been filled. (neg 4266)

HOW TO INCREASE CUPOLA EFFICIENCY

by

R.D. Warda

"Over one-half the energy required to produce an iron casting is expended in the melt shop" was one of the statements Bob Buhr made yesterday in his introductory message. Since the greatest potential for reducing any expenditure, whether it be cost or energy, is proportional to its magnitude, the iron foundry melt shop should be a high priority in any energy conservation program. If you are melting with a cupola, imported coke at $200 a ton is an added incentive to improve melting efficiency.

The melting efficiency of iron foundry cupolas has been the subject of a coast-to-coast survey we have been conducting during the past year and I would like to leave with you a summary of this survey. The project began with a telephone survey to explain our goals, determine if the foundries were interested and obtain sufficient information to ensure that the 30 foundries selected for testing represented a wide range of size, design, operating practice and metal demand. This data was incorporated later in the body of information gathered during the in-plant tests to provide a comparison between what the foundries thought was happening in their cupola and what was actually happening.

METHODOLOGY

Figure 1 schematically summarizes all parameters used to characterize the cupola and its operation and assess its performance. These parameters can be subdivided into the following groups:

1. Cupola - dimensions and design features.
2. Inputs - blast, coke, metallics, flux, alloys.
3. Outputs - metal, slag, stack gas, contents of drop.
4. Operating characteristics - charge door flame, slag colour and texture, bed preparation practices, bed height, burden height during operation.

Cupola Dimensions and Design Features

Each cupola was measured after refractory repairs were completed and the following dimensions were noted:

- internal diameter in the well, melt zone and upper stack
- size and location of the taphole and slag hole
- size, location and number of rows of tuyeres
- height of the charge door above the uppermost tuyeres.

After the bottom was dropped and the furnace cooled, the melt zone diameter was determined at 300 mm (12 in.) intervals above the tuyeres to define the melt zone profile and determine the refractory wear rate. Relevant features such as divided blast, hot blast, oxygen enrichment, refractory type and watercooling of the shell were noted and quantified if possible. Process control equipment such as air-weight controllers and charge scales were examined and recalibrated when necessary.

Cupola Inputs

The blast was characterized by measuring its rate, temperature, oxygen content and humidity. The rate was determined in the blast duct using methods recommended by the ASTM and EPA for stack gas sampling. The blast rate in the cupola was then determined by inspecting the ducting, windbox and tuyeres for leakage and making an appropriate reduction in the measured blast rate. This reduction ranged from 5 to 20 percent depending on the severity of the leakage. Blast temperature and oxygen content were determined as close to the tuyeres as possible to ensure that the measurements were characteristic of the air entering the cupola. Oxygen content in enriched blast systems was measured with an Orsat analyzer. Humidity of the air near the blast system inlet was measured with a sling psychrometer.

Charge materials - metallics, coke, fluxes and alloys were evaluated primarily by weight and size, although other characteristics such as cleanliness, amount of rust and the presence of non-ferrous scrap were noted. The determination of the weight of charge metallics presented serious problems in a number of the foundries. In these foundries, weight was determined either by an "internally calibrated" charge-hand, by the use of a charge bucket which held "about 800 pounds" or by scales which were clearly inaccurate. In the first two cases, we participated independently in the "weighing" process and

arrived at a mutually agreeable conclusion which was compared later with the pour weight, also usually estimated.

In the case of defective or inaccurate scales, we attempted to perform a calibration using any pre-weighed commodity, such as bags of sand, boxes of patch, which was available. Determination of the coke weight presented a similar but less difficult problem. By careful observation of how many and how full each fork, box, tub or wheelbarrow of coke was, and by weighing a typical "unit" of coke later, reasonably accurate weights were determined. Limestone additions were checked in a manner similar to that used for coke. Proprietary fluxes and ferroalloy additions were normally added in the form of bricks which simplified the determination of their weights.

Cupola Outputs

Cupola outputs were evaluated quantitatively to enable heat and material balances to be calculated, and qualitatively, to define characteristics which the operator can use to "read" the cupola. The most important output - the molten iron - was subjected to regular determinations of temperature, melting rate, chill depth and composition. Temperature was measured in the cupola spout using a portable immersion thermocouple. Depending on the metal handling system, temperatures were also determined in the forehearth, transfer ladle, and during pouring at the mould. For continuous tap cupolas, the melting rate was determined by measuring the time required to fill a 9 kg (20 lb) hand-shank ladle inserted in the tap stream. The melting rate for intermittently tapped cupolas was measured indirectly by one or more of the following methods: determination of the total melt time and pour weight; determination of the numbers of ladles of known capacity which were filled per hour; comparison with the metal charging rate.

Metal and slag samples were taken at regular intervals, visually checked for immediate feedback and then retained for subsequent chemical analysis. Metal samples were taken directly from the tap stream and poured into an ASTM wedge block core for chill depth measurement. Later, a portion of the chill sample was crushed and analyzed for carbon using a combustion method and for silicon, manganese, sulphur and phosphorus using wet chemistry procedures. Slag samples were taken using the metal mould and procedures recommended by the Gray Iron Research Institute (1). Upon cooling, each

sample was examined for colour, texture and fracture characteristics in an attempt to relate these characteristics to melting conditions. Each sample was then subdivided into several large pieces having typical visual and textural qualities while the remainder of the sample was crushed and analyzed for the major constituent oxides - SiO_2, MgO, CaO, Al_2O_3 and FeO.

Stack gas conditions were determined in a zone ranging from 600 to 1500 mm (2 to 5 ft) below the charge door. Sampling was conducted at various locations in the stack cross-section to ascertain the effects of gas channeling in regions of low charge density. Temperatures were recorded either as the maximum and minimum for each charge cycle or as an average value. The charge level was noted for each temperature reading. Regular CO_2 determinations were made with a Fyrite analyzer. Periodic tests were performed with an Orsat unit to confirm the Fyrite results and to determine the oxygen content. CO concentrations were calculated from the known levels of CO_2 in the stack gas and O_2 in the blast air.

While not considered a normal output, the contents of the cupola drop were identified and their weights estimated for subsequent use in the material balance calculations.

Simultaneous heat and material balance calculations were performed on the data obtained during the daily melting period at each foundry. These calculations presented considerable difficulties because of short melting periods and non-equilibrium behaviour exhibited by many of the cupolas. These difficulties were resolved by the use of a modified material/heat balance which took account of the fact that the cupola bed height did not remain constant during the melt.

RESULTS

I would now like to summarize the results of over sixty days of cupola testing and give examples of specific behaviour of selected cupolas. To identify the numerous variables which determine melting efficiency in a foundry, the data are presented in the form of two melting systems. The first system includes only the cupola and can be used to relate melting performance to cupola design and operating practice. The second system also contains the cupola, but extends considerations to variables external to the cupola such as coke losses and melting time.

Cupola Melting Performance

In this section metal:coke ratios, melting efficiency (M.E.) values and examples of trends in stack gas composition and metal temperature are presented. When used in conjunction with the Appendix, these data define the performance of the cupola alone and relate this performance to its design and operation.

Table 1 uses metal:coke ratios and melting efficiency values to describe and rank cupola performance in 3 different contexts. In the first context, the cupolas are ranked by their nominal metal:coke ratio. This ranking number also identifies each cupola by a number which will be used throughout the presentation. (The nominal metal:coke ratio is the charge metal:charge coke ratio quoted by foundry personnel during the preliminary telephone survey and later confirmed on site.) In addition to the numbers, letter suffixes are used to describe two different cupolas (15, 15a) at one foundry and a single cupola at another which was tested twice to determine the effect of changes in cupola design and practice.

In the second case, actual melting efficiencies and metal:coke ratios are shown for the daily conditions at each cupola. The melting efficiency is the useful heat output, in the form of hot metal at the spout, expressed as a percentage of the total heat input. This input includes potential heat in the coke, sensible heat in the blast, heat of oxidation of silicon, and heat of slag formation. The actual coke ratio is the ratio of the metal melted to the net coke consumed during the daily operation. The net coke consumed was calculated by considering the coke combusted, that lost as fines in the stack, the quantity used to decompose blast moisture and the coke dissolved as carbon in the metal. The net coke was also measured by subtracting the coke in the drop at the end of the melt from the total coke input-bed, charge and booster coke. As with the nominal coke ratios, the cupolas are ranked according to actual melting efficiency and coke ratio.

Although the actual efficiency and coke ratio accurately describe the performance of an individual cupola, there are too many differences between cupolas to permit a meaningful comparison. Accordingly, the data were normalized to eliminate the influence of metal temperature, blast conditions and carbon pickup on the melting efficiency and metal:coke ratio. As a first step, metal temperatures were normalized to 1480°C (2700°F) in the following manner. AFS and BCIRA data (2,3) were used to define the relationship

between metal temperature and melting efficiency as shown in Fig. 2. In this illustration each curve has been generated by changing the metal:coke ratio and/or blast rate of a cupola operated under otherwise similar conditions. If the 30 test cupolas were manipulated similarly, it is probable that their efficiency-temperature relationships would also be defined by similar curves. As shown in Fig. 3, the data for the test cupolas were therefore superimposed on a family of curves, the center of which was the average for the AFS/BCIRA data. The efficiency of each cupola whose efficiency-temperature was defined by a point lying within the family of curves was then normalized by displacing that point parallel to the curves until a new efficiency was determined at a spout temperature of 1480°C (2700°F). Normalization of the cupola performance was completed by recalculation of the material/heat balances to yield the melting efficiencies and metal:coke ratios in Table 1 defined by the following conditions:

1) Metal temperature at the cupola spout, 1480°C (2700°F)
2) Blast air at 21°C (70°F), 50% relative humidity
3) 96.3% of the total heat input provided by the coke*
4) No carbon pickup
5) 2% of the charge coke lost as stack gas particulate

Although much of the data describing the operation of individual cupolas is of necessity the average of numerous measurements, it is essential to the accurate description of the cupola operation that certain variables be presented in greater detail. Figures 4-6 illustrate the complete daily results for stack gas CO_2 levels and metal spout temperatures for three different cupolas. Figure 4 shows non-equilibrium melting behaviour typical of that found in many cupolas which were operated only for a short time each day. Assuming constant blast conditions, the rising CO_2 curve indicates a bed height which is decreasing as melting progresses. At a critical point, which appears to differ for each cupola, the metal temperature decreases, the chill depth increases, and the slag becomes black and porous. Figure 5 illustrates similar non-equilibrium behaviour for a larger cupola. However, in this case the trend is much slower and metal and slag conditions did not change signficantly because the minimum critical bed height was not reached.

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*Remainder of heat input supplied by heat of blast, oxidation of silicon, and heat of formation of slag.

Figure 6 shows non-equilibrium behaviour in a cupola in which the trend in stack gas CO_2 content is opposite to those shown in Figs. 4 and 5. In this situation the decreasing CO_2 level resulted from a bed height which increased because of the unnecessary periodic addition of booster coke.

Melting Department

In this section melting efficiency, metal:coke ratios and coke costs per ton of metal melted were used to define the performance of the melting department of each foundry tested. Data are also presented showing the influence on melting department performance of the following foundry variables: disposal of drop coke, coke handling losses, length of melt, and temperature losses during metal handling.

Table 2 describes and ranks the actual performance of each melting department. The three performance criteria and their definitions are as follows. Melting efficiency is the heat content of the metal at the cupola spout expressed as a percentage of the total heat input, including heat contained in the coke lost during handling and discarded from the drop. Metal: coke ratio is the weight of metal melted divided by the sum of the coke consumed in the cupola plus the coke lost during handling and discarded from the drop. The coke cost is the purchase price of the coke, assumed to be $232/ tonne ($210/ton) F.O.B. the foundry, divided by the overall metal:coke ratio. Finally, handling losses, defined as the difference between the purchased weight of the coke and the weight charged into the cupola, were assumed to be 10%.

In evaluating the performance of a foundry melting department, the first step should be a comparison between melting department performance and that of the cupola alone. Figure 7 facilitates this comparison by expressing the relationship between actual melting department coke ratios and actual cupola coke ratios as a percentage and showing how this relationship varies with the length of the melt. Table 3 extends the overall melting performance concept to include delivery of hot metal to the mould. This table describes the actual conditions (cases A and D) for foundries 6 and 24. Metal temperature at the cupola spout, receiver spout and mould are described. Cupola melting efficiency and melting department performance data are taken from Tables 1 and 2 respectively. Melting efficiency at the mould is the heat content of the metal at the mould expressed as a percentage of the total

overall heat input, as defined for Table 2. In the hypothetical situations shown in cases B and E, the excessive receiver losses of 170°C (300°F) were reduced to 100°C (180°F) and 90°C (160°F) respectively, resulting in pouring ladle temperatures higher than those desired. This excess superheat can be eliminated readily either by adding scrap to the ladle or by reducing the metal temperature at the cupola spout. Cases B and E show the effect on melting performance and the resultant coke saving if the metal is cooled with scrap. Cases C and F show the benefits of modifying the cupola operation to reduce the metal temperature at the cupola spout.

DISCUSSION

Consideration of the nominal, actual and normalized cupola melting efficiencies and coke ratios in Table 1 immediately identifies certain key aspects of cupola behaviour. The nominal ratios start with an exemplary 15.4:1 and decrease to 5.5:1 and 3.8:1 for two cupolas which used small blast furnace coke. The nominal ratio, especially if it is 15:1, is often quoted without explanation at foundry meetings, producing an undeserved admiration among those unfamiliar with the cupola, and causing great problems for the other cupola operators. Unfortunately, the nominal metal:coke ratio bears little resemblance to actual cupola performance, and even less to overall melting efficiency.

Actual metal:coke ratios based on the measured inputs and outputs of each cupola, are substantially lower than the corresponding nominal ratios. In addition, the reduction in coke ratio varied from cupola to cupola, producing numerous changes in rankings. For example, cupola No. 1, with the best nominal coke ratio, is ranked 29th in actual coke ratio. The primary reason for such marked differences is non-equilibrium melting behaviour in which the coke charging rate does not equal the rate of bed coke consumption. The result is a coke bed height which varies during melting, causing the behaviours shown in Figs. 4-6, as well as changes in both metal and slag characteristics. Figure 4 illustrates the rapid changes occurring in cupola No. 1 which result from the great disparity between nominal (15.1:1) and actual (4.7:1) coke ratios. In this cupola, 570 kg (1250 lb) of bed coke were consumed in addition to the charge coke during a melt which lasted 65 min. Cupolas exhibiting similar behaviour were observed to be wasting

coke in two ways: directly, because the starting coke bed was too high, and indirectly through increasing production of scrap toward the end of the melt when the bed became too low to maintain adequate temperature and chill characteristics. Figure 5 describes the behaviour of a cupola whose coke bed was excessively high initially and which dropped slowly during the melt. Calculations using the modified non-equilibrium heat balance showed this cupola was wasting 1800 kg (4000 lb) of coke per day, most of which was escaping as latent heat in the stack gas. Figure 6 shows a trend in melting behaviour opposite to that in Fig. 5. but which also resulted in coke wastage. In this cupola, which was initially producing acceptable metal, the unnecessary addition of booster coke increased the height of the coke bed resulting in a decrease in efficiency.

The actual melting efficiencies in Table 1, in conjunction with the other heat outputs described in the Appendix, define the performance of each cupola more accurately than the metal:coke ratio because more variables are accounted for in the heat balance. To avoid the comparison between "Apples, Oranges and Coke" (4), the cupola performance results were normalized.

The first stage in the normalization process was a determination of the relationship between melting efficiency and metal temperature, shown graphically in Fig. 2. This figure not only emphasizes the long-known fact (5,6,7) that the cupola is an inefficient superheater, but also points to the importance of metal temperature in determining cupola efficiency. The slopes of the curves between 1430°C (2600°F) and 1540°C (2800°F) can be shown to correspond to superheating efficiencies of only 3.5 to 5 percent. The practical implication of this extremely low superheating efficiency is that reducing metal temperature at the cupola spout is one of the most effective methods of increasing melting efficiency. For example, an average cupola producing metal at 1540°C (2800°F) will have an actual efficiency of 25-30%; changing the operating conditions of the same cupola to produce metal at 1450°C (2650°F) will increase the efficiency to 43-50%. This increase in efficiency would result in an overall saving of coke costs of $20/tonne ($18/ton) of metal, or $320/day for a 4 tonne/h cupola operated 4 h/day.

The normalization process was completed by standardizing the effects of coke-consuming processes in the cupola such as decomposition of the blast moisture, entrainment of coke fumes in the stack gas, and solution of the carbon in the metal. The results - the normalized melting efficiencies and

coke ratios shown in Table 1 - are the most accurate criteria of both absolute and relative cupola performance. They are used to rank the cupola data presented in the Appendix to permit a valid comparison between cupolas and to identify design and operation variables which signficantly affect cupola performance.

Having described the performance of each cupola alone, and having shown that this performance can be improved to produce substantial coke savings, we will now examine the melting department efficiency and its relationship to variables external to the cupola. Table 2 describes melting department performance using purchased coke as the input and metal at the spout as the output. The significant and varied differences between cupola melting performance, described in Table 1, and the melting department performance in Table 2 are caused by 3 factors: coke handling losses within the foundry, coke lost in the cupola drop, and the length of the melt.

Figure 7 summarizes the influence of coke losses and melt time on the relationship between cupola and melting department coke ratios. Examination of this figure reveals several important aspects of this relationship. Firstly, because of the 10% coke handling loss, the upper limit for the melting department coke ratio is 90% of the cupola coke ratio. Secondly, when the coke lost in the drop is also included, the melting department coke ratio not only decreases further, but also becomes very sensitive to melt times of less than 5 hours. Finally, when the variability produced by different melt times and the loss of different amounts of drop coke is added to the existing differences between cupola melting performances, a four-fold range of melting department performance and coke costs is produced.

The practical implications of the influence of coke losses and melting time on melting department performance are as follows:

1) Increasing the daily melt time from 1 to 4 hours generally will produce a 20-30% increase in melting efficiency and a corresponding reduction in coke costs.
2) Further increases in efficiency and coke savings can be achieved by minimizing handling losses and increasing the recovery of bed coke.

Expanding the context of melting department performance further to include metal delivery to the mould identifies temperature losses during metal handling as a major cause of poor performance (8). Table 3 shows how excessive temperature losses in the receiver resulted in low cupola

efficiency and poor melting department performance. A reduction in receiver losses to normal values and the removal of excess superheat by the addition of scrap to the pouring ladle produced no increase in cupola efficiency, a modest increase in melting department efficiency and a negligible reduction in daily coke costs. However, when the reduction in receiver losses was used to reduce the metal temperature at the cupola spout, both the cupola and melting department efficiencies increased signficantly and the savings in daily coke costs were substantial.

Consideration of both the cupola and the overall melting performance of the cupola operations at 30 foundries has revealed large variations in melting efficiencies, coke ratios and coke costs, and equally great opportunities for improvement in performance and reduction in coke costs. As a guide to improved cupola operation, Table 4, which summarizes the Appendix by describing the average characteristics of the 10 best and 10 worst cupolas, will be used in conjunction with the data presented previously to list the qualities of an "ideal" cupola operation. For optimum melting efficiency, the cupola should have the following design and operating characteristics:

1) the largest melt zone diameter permitted by shell size and metal demand,
2) a minimum charge door height above tuyeres of 6 m (20 ft),
3) divided blast with oxygen enrichment and hot blast,
4) a refractory lining (compatible with other operating requirements),
5) a minimum height of watercooled shell, if the operation is liningless,
6) tuyeres as low as possible, considering the tapping method and carbon pickup required,
7) blast weight control and complete charge weighing,
8) continuous or regular measurement of metal temperature,
9) continuous or regular measurement of stack gas CO_2 content,
10) regular measurement of metal chill depth and/or carbon equivalent,
11) analysis of charge door flame and slag characteristics to determine melting conditions,
12) specific melting rate in the range 7.4-9.8 tonnes/m^2/h (0.75-1.0 tons/ft^2/h),

13) specific blast rate consistent with 12), but preferably in the range 92-122 Nm^3/m^2 (300-400 $SCFM/ft^2$),

14) adjustment of cupola conditions to produce metal at the minimum spout temperature consistent with foundry requirements,

15) determination of bed and charge coke weights to provide equilibrium melting conditions with the minimum bed height permitted by 14), and

16) adequate fluxing to facilitate combustion and carbon pickup.

For optimum melting department performance, the "ideal" foundry melting department should also have the following operating conditions:

1) optimum cupola melting efficiency as defined above,

2) melt times as long as possible, but at least 4 hours,

3) maximum recovery of drop coke,

4) minimum coke handling losses, and

5) minimum temperature losses during metal handling.

For the foundryman attempting to improve the performance of an existing cupola operation, some of the recommendations may seem irrelevant. Increasing the height or lowering the tuyeres may not be practicable, nor would installing hot blast on a small cupola melting for only one hour or two per day. But a recommendation can also offer insight into indirect benefits. For example, while it may not be feasible to increase the actual height of a cupola, its effective height can be increased by keeping it full and ensuring that the scrap is small and well-distributed.

These precautionary comments not withstanding, the lists contain many proven, practicable suggestions for improving cupola operations through changes in design, operation and utilization. The outstanding performances of the two divided blast cupolas indicate that divided blast (3) should be the first design change considered, provided that the cupola has adequate stack height. Its only drawback is an increased quantity of bed coke which could reduce the overall melting efficiency unless precautions are taken to improve drop coke recovery and increase melt times. Both oxygen enrichment and hot blast were used by a significant number of the better cupolas suggesting that these features can also contribute to increased melting efficiency. These results agree with previous enrichment (9,10,11) experience. The use of oxygen on 2 of the 10 worst cupolas is neither a contradiction nor an indictment of this process; rather, it is a warning that enrichment or any new technology <u>per se</u> cannot overcome the effects of deficiencies in cupola

design and operation. Recuperative hot blast systems produce signficant increases in melting efficiency (12,13,14), but the effects of independently fired hot blast systems similar to those tested, are less clear. While coke consumption can be reduced substantially, heat balance analyses disagree on the effect of independently fired hot blast on melting efficiency (15,16). However, the benefits of oxygen enrichment and hot blast extend beyond the improvement of cupola melting efficiency alone. If used correctly, these features can improve cupola control (9,10,17,18,19), thus increasing overall efficiency by increasing yield (10,20) and reduce charge costs by increasing carbon pickup and reducing silicon losses (10,21,22).

Although the theoretical limit of cupola melting efficiency might be set by cupola design, the operation and control of the cupola determine how closely and consistently the design limit can be approached during daily operations. The influence of charging practice on the difference between actual and effective cupola heights has been discussed. Correct balancing of charge and bed coke can not only reduce stack gas heat losses by avoiding excessive coke bed depths, but can also increase overall efficiency by reducing scrap losses resulting from inadequate bed heights. Figure 5 is an example of the former; our calculations showed that a very high initial bed depth resulted in the loss of 1800 kg (4000 lb) of coke/day as unrecovered latent stack gas heat. On the other hand, at the end of the melt described in Fig. 4, an inadequate bed height resulted in a high scrap rate caused by misruns, cold-shuts and excessive chill depth.

The non-equlibrium melting conditions responsible for the inefficient performances shown in Figs. 4-6 are manifestations of inadequate control of the cupola operation resulting from a lack of understanding of the basic melting process. Poor control of the material inputs to the cupola can also result in poor and variable cupola performance. At one foundry in which neither the blast nor the metallic charge were weighed, we noted the spout temperature of 1540°C (2800°F) was excessive. When questioned, one of the pouring crew replied, "She's smokin' hot today but yesterday she was so dull we couldn't pour". This foundry was paying the price of poor control - excessive scrap one day, and unnecessary superheat the next. However, neither Table 4 nor the list of recommendations for an ideal cupola touch upon the real cause of poor control. Air-weight meters and charge scales alone do not ensure control; the essential ingredient is a knowledgeable and

attentive staff, from melter to manager. While not quantifiable, this factor varied from foundry to foundry, and was clearly related to cupola performance.

Although good design and operating practice are required for optimum cupola performance, overall melting performance also depends on variables external to the cupola. Furthermore, as the context of this overall performance is expanded, external variables increase both in numbers and in the extend to which they collectively influence performance. Reducing coke losses can increase melting department efficiency by 10%. Increasing melt times from 1 to 4 h, or decreasing metal temperatures by 55°C (100°F) provides a further increase in overall efficiency at no cost which is equivalent to that offered by divided blast or oxygen enrichment.

CONCLUSION

1) The cupola is a single but important link in the foundry processing chain and although an evaluation of melting efficiency should focus on the cupola, it should also include the rest of the foundry.
2) Performance of the 30 cupolas could be described as follows:
   a) Nominal performance: metal:coke ratios varied from 15.4:1 to 3.8:1
   b) Actual Performance: coke ratio, 10.3:1 to 2.1:1; efficiency, 46.5% to 9.1%
   c) Normalized performance: coke ratios ranged from 11.4:1 to less than 4.1:1 and efficiency varied from 53% to less than 19%.
3) Differences between nominal and actual performances were due primarily to non-equilibrium melting conditions, while the strong dependence of cupola melting efficiency on spout temperature was the main reason for variations between actual and normalized performances.
4) The ranking of the cupolas according to normalized melting efficiency identified the following as key variables affecting cupola performance:
   a) metal temperature at the cupola spout,
   b) divided blast, oxygen enrichment and hot blast,
   c) melt time,
   d) cupola control,
   e) cupola size and height.
5) Factors exernal to the cupola which play a significant role in determining overall melting performance are:

a) coke losses,

b) temperature losses during metal handling,

6) Many of the foundries tested could implement one or more of the following "no-cost" improvements and obtain the substantial savings shown in parentheses.

a) Increase melt time from 1 to 4 h ($10-$20/tonne ($9-$18/ton) of hot metal).

b) Reduce spout temperature ($15-$20/tonne ($13-$18/ton) of hot metal for a reduction of 80°C (150°F)).

c) Reduce coke losses ($5-$10/tonne ($4-$9/ton) of hot metal).

d) Improve cupola practice and control (significant but indeterminate savings).

7) After establishing a fundamentally sound, controlled cupola operation, additional improvements in melting efficiency can be obtained by selectively implementing better technology such as divided blast, oxygen enrichment, hot blast, tuyere injection of coke breeze, etc.

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REFERENCES

1. A. Stone, Gray Iron Research Inst. Inc., Private Communication.

2. "Cupola Handbook"; Cupola Research Committee, American Foundrymen's Society, Des Plaines IL 60016, USA (1975).

3. H.J. Leyshon, M.J. Selby, "Improved Cupola Performance by Correct Distribution of the Blast Supply Between Two Rows of Tuyeres"; British Foundryman, vol 65, p 43-55 (1972).

4. R.W. Lobenhofer, "Apples, Oranges and Coke"; Modern Casting, vol 69, p 41 (Jul 1979).

5. G.K. Elliott, "Superheats in the Electric Furnace"; Foundry, vol 49, p 714-719 (1921).

6. H.W. Lownie, "Some New Factors Affecting Cupola Operation"; Modern Casting, vol 49, p 99-106 (Jun 1966).

7. J.E. Rehder, "Modern Iron Melting Techniques and Their Applications"; Paper No. 29, 33rd International Foundry Congress, New Dehli (1966).

8. R.A. Clark, "Gray Iron Heat Conservation"; American Foundryman, vol 20, p 40-43 (Oct 1951).

9. A.P. Bower, "Oxygen Enrichment Experience"; British Foundryman, vol 68, p 314-319 (1975).

10. H.C. Rolseth, "The Effect of Oxygen Enrichment on Energy Consumption in Iron Cupola Melting"; AFS Transactions, vol 84, p 295-298 (1976).

11. G. Powner, D. Rogers, R.J. Turley, "The Economic Advantages of Recent Improvements in Cold Blast Melting Practice"; British Foundryman, vol 71, p 135-143 (1978).

12. F.K. Vial, "Savings from Hot Blast Cupola"; Iron Age, vol 120, p 1155-1156 (1927).

13. L.G. Berryman, "Air Preheater Unit for Small Cupola Aids Melt Efficiency"; American Foundryman, vol 20, p 40-42 (Nov 1951).

14. Anon. "Hot Blast Cupola Practice"; Foundry Trade J, vol 96, p 362 (1954).

15. F.C. Evans, "Operation and Design of Hot Blast Cupolas"; Foundry Trade J, vol 91, p 247-251, 279-282 (1951).

16. W. Patterson, B. Kohler, "Influence of a Blast Temperature of 500°C on Performance, Heat Balance and Some of the Processes Occurring in the Cupola"; Giessereiforschung in English, vol 23, No. 3, p 95-108 (1971).

17. A.W. Gregg, "Oxygen and Cupola Operation"; Foundry, vol 76, p 86-90 (Jun 1948).

18. Anon. "Cupola Development - Report of Sub-Committee T.S. 43 of the Technical Council of the Inst. of Br. Foundrymen"; Foundry Trade J, vol 97, p 47-51, 69-75 (1954).

19. E.L.W. Loebbecke, "Development of Hot Blast Melting Technique in Europe"; AFS Transactions, vol 64, p 171-196 (1956).

20. C. Gresty, "Fuel Economy in the Iron Foundry"; Foundry Trade J, vol 72, p 31-34 (1944).

21. F.K. Vial, "Economics of Cupola Operational Control"; AFS Transactions, vol 54, p 507-541 (1946).

22. G.A.H. Jungbluth, K. Stockamp, "Chemical Reactions in the Cupola"; Foundry Trade J, vol 99, p 377-387, 405-411, 643-650 (1955).

Table 1. Nominal, actual and normalized cupola melting performance.

Cupola melting performance							
Nominal		Actual			Normalized		
Foundry No.	M:C 1	Foundry No.	M.E. %	M:C 2	Foundry No.	M.E. %	M:C 1
1	15.4:1	2	46.5	10.3:1	5	53.0	11:4:1
2	11.1:1	4	41.0	9.8:1	2	53.0	11.4:1
3	10.8:1	5	45.5	9.2:1	15	43.0	9.3:1
4	10.5:1	6	38.2	8.6:1	27	41.0	8.8:1
5	10.4:1	9	37.8	8.2:1	4	41.0	8.8:1
6	10.0:1	14	36.0	8.1:1	19	41.0	8.8:1
7	10.0:1	15	34.4	7.7:1	15a	39.0	8.4:1
8	10.0:1	16	35.4	7.7:1	6	38.5	8.3:1
9	9.5:1	7	33.8	7.7:1	9	38.0	8.2:1
10	9.1:1	19	35.7	7.5:1	14	37.5	8.1:1
11	9.1:1	15a	32.5	7.3:1	23	37.0	8.0:1
12	9.1:1	21	30.7	7.0:1	28	37.0	8.0:1
13	9.1:1	10	32.3	7.0:1	16	33.0	7.1:1
14	8.8:1	22	31.8	6.8:1	21	32.5	7.0:1
15	8.8:1	17	28.7	6.7:1	29	32.5	7.0:1
16	8.8:1	11	28.1	6.7:1	24	29.0	6.3:1
15a	8.4:1	23	30.4	6.6:1	22	28.5	6.1:1
17	8.3:1	26	28.9	6.6:1	10	28.0	6.0:1
18	8.1:1	27	28.2	6.2:1	26	27.5	5.9:1
19	8.0:1	20	29.1	6.2:1	12	27.0	5.8:1
20	8.0:1	12	26.9	6.0:1	8	26.0	5.6:1
10a	8.0:1	10a	27.6	6.0:1	7	25.0	5.4:1
21	7.4:1	18	25.7	6.0:1	13	22.5	4.9:1
22	7.3:1	24	26.8	5.9:1	3	20.0	4.3:1
23	7.2:1	13	25.7	5.8:1	10a	19.5	4.2:1
24	7.1:1	3	26.0	5.7:1	20	19.0	4.1:1
25	7.0:1	8	26.1	5.7:1	1	19.0	4.1:1
26	6.8:1	28	26.3	5.6:1			
27	6.7:1	1	21.2	4.7:1	The efficiencies of cupolas 11, 12, 18, 25 and 30 were too low to normalize.		
28	6.0:1	29	21.4	4.5:1			
29	5.5:1	25	10.7	2.5:1			
30	3.8:1	30	9.2	2.1:1			

Table 2. Summaries of melting department performance and overall foundry melting performance.

Melting department performance									
50% Coke drop lost					100% Coke drop lost				
Fdry No.	M.E. %	M:C	Coke cost $/tonne	($/ton)	Fdry No.	M.E. %	M:C	Coke cost $/tonne	($/ton)
2	39.4	8.7:1	26.55	(24.14)	2	37.1	8.2:1	28.17	(25.61)
4	34.3	8.1:1	28.52	(25.93)	4	31.9	7.5:1	30.80	(28.00)
5	38.1	7.8:1	29.61	(26.92)	5	36.0	7.4:1	31.22	(28.38)
6	33.4	7.5:1	30.80	(28.00)	6	32.1	7.2:1	32.08	(29.16)
14	31.2	7.0:1	33.00	(30.00)	14	30.3	6.8:1	33.97	(30.88)
19	31.8	6.7:1	34.47	(31.34)	19	31.8	6.7:1	34.47	(31.34)
15	29.6	6.6:1	35.00	(31.82)	15	27.9	6.1:1	37.26	(33.87)
16	29.3	6.4:1	36.09	(32.81)	16	27.9	6.1:1	37.87	(34.43)
15a	28.1	6.3:1	36.66	(33.33)	15a	27.3	6.1:1	37.87	(34.43)
7	27.2	6.2:1	37.26	(33.87)	7	24.6	5.6:1	41.25	(37.50)
9	28.4	6.2:1	37.26	(33.87)	27	25.6	5.6:1	41.25	(37.50)
21	26.0	5.9:1	39.15	(35.59)	9	24.7	5.4:1	42.78	(38.89)
17	24.4	5.7:1	40.52	(36.84)	17	22.7	5.3:1	43.58	(39.62)
27	25.6	5.6:1	41.25	(37.50)	21	23.0	5.2:1	44.42	(40.38)
11	23.5	5.6:1	41.25	(37.50)	11	21.9	5.2:1	44.42	(40.38)
23	25.3	5.5:1	42.00	(38.18)	23	23.9	5.2:1	44.42	(40.38)
10	25.2	5.5:1	42.00	(38.18)	26	22.0	5.0:1	46.20	(42.00)
22	25.1	5.4:1	42.78	(38.89)	22	22.3	4.8:1	48.13	(43.75)
26	22.9	5.2:1	44.42	(40.38)	10	21.9	4.8:1	48.13	(43.75)
12	22.4	5.0:1	46.20	(42.00)	12	21.5	4.8:1	48.13	(43.75)
24	22.7	5.0:1	46.20	(42.00)	24	21.3	4.7:1	49.15	(44.68)
28	23.0	4.9:1	47.15	(42.86)	28	22.0	4.7:1	49.15	(44.68)
10a	21.4	4.7:1	49.15	(44.68)	10a	19.5	4.3:1	53.72	(48.84)
20	21.7	4.7:1	49.15	(44.68)	20	18.8	4.1:1	56.34	(51.22)
3	20.4	4.5:1	51.34	(46.67)	3	18.1	4.0:1	57.75	(52.50)
13	20.0	4.5:1	51:34	(46.67)	13	17.3	3.9:1	59.24	(53.85)
18	18.4	4.3:1	53.72	(48.84)	18	15.8	3.7:1	62.44	(56.76)
8	18.7	4.1:1	56.34	(51.22)	1	16.7	3.7:1	62.44	(56.76)
1	18.0	4.0:1	57.75	(52.50)	29	16.6	3.5:1	66.00	(60.00)
29	18.0	3.8:1	60.79	(55.26)	8	15.5	3.4:1	67.94	(61.76)
25	9.0	2.1:1	89.10	(81.00)	25	8.1	1.9:1	98.42	(89.47)
30	7.4	1.7:1	110.00	(100.00)	30	7.0	1.6:1	116.88	(106.25)

Table 3. Effect of temperature losses in the receiver on cupola melting efficiency and melting department performance.

Foundry No./case	Metal temperature			Cupola	Melting department			
	Cupola spout °C (°F)	Receiver spout °C (°F)	At mould °C (°F)	M.E. %	M.E. at mould	M:C	Coke cost $/tonne ($/ton)	Coke saving $/day*
6/A	1482 (2700)	1315 (2400)	1288 (2350)	38.2	26.3	7.5	30.80 (28.00)	0
6/B	1482 (2700)	1382 (2520)	1288 (2350)	38.2	29.2	7.9	29.30 (26.60)	38.40
6/C	1416 (2580)	1315 (2400)	1288 (2350)	56.5	41.7	11.4	20.30 (18.40)	248.00
24/D	1493 (2720)	1327 (2420)	1288 (2350)	26.8	17.8	5.0	46.30 (42.00)	0
24/E	1493 (2720)	1404 (2560)	1288 (2350)	26.8	19.9	5.3	43.70 (39.00)	36.50
24/F	1416 (2580)	1327 (2420)	1288 (2350)	46.5	32.3	8.7	26.60 (24.10)	263.00

*Based on actual data: FDY No. 6: - 4.2 tonne/h (4.65 ton/h), 5.5 h/day.
FDY No. 24: - 3.6 tonne/h (3.95 ton/h), 3.7 h/day.
Coke cost: - $232/tonne (/ 210/ton).

Case A: - As tested, receiver loss 167°C (300°F).
Case B: - Hypothetical, receiver loss 100°C (180°F), metal cooled 67°C (120°F) with scrap.
Case C: - Hypothetical, receiver loss as in B, spout temperature reduced 67°C (120°F).
Case D: - As tested, receiver loss as in A.
Case E: - Hypothetical, receiver loss 89°C (160°F), metal cooled 78°C (140°F) with scrap.
Case F: - Hypothetical, receiver loss as in E, spout temperature reduced 78°C (140°F).

Table 4. Comparison of average characteristics of the 10 best cupolas with those of the 10 worst cupolas.

Characteristic		Best 10	Worst 10
Cupola melting efficiency,	%	37.6±5.6	27.2±3.2
Stack gas latent heat,	%	29.3±9.1	23.7±10.5
Stack gas sensible heat,	%	12.2±4.6	18.6±7.0
"Shell" losses,	%	14.4±6.9	23.0±5.2
Melt time,	h	8.8±4.1	1.8±1.1
Melt zone diameter,	cm (in)	126±38 (49.6±15.1)	82±23 (32.1±9.0)
Height, tuyeres-charge door,	m (in)	5.2±1.2 (203±48)	4.3±0.8 (168±30)
Metal temperature,	°C (°F)	1505±24 (2742±44)	1440±33 (2625±60)
Combustion ratio,	%	55±15	61±11
Specific blast rate,	$Nm^3/m^2/min$ ($SCFM/ft^2$)	97±26 (318±85)	103±18 (339±58)
Specific melt rate,	$Tonnes/h/m^2$ ($Tons/h/ft^2$)	7.9±1.6 0.81±0.16	5.8±0.9 (0.59±0.09)
Blast control		9/10	1/10
Metallics weighed		9/10	7/10
Coke measured		10/10	9/10
Hot blast		4/10	0/10
Oxygen enrichment		6/10	2/10
Divided blast		2/10	0/10

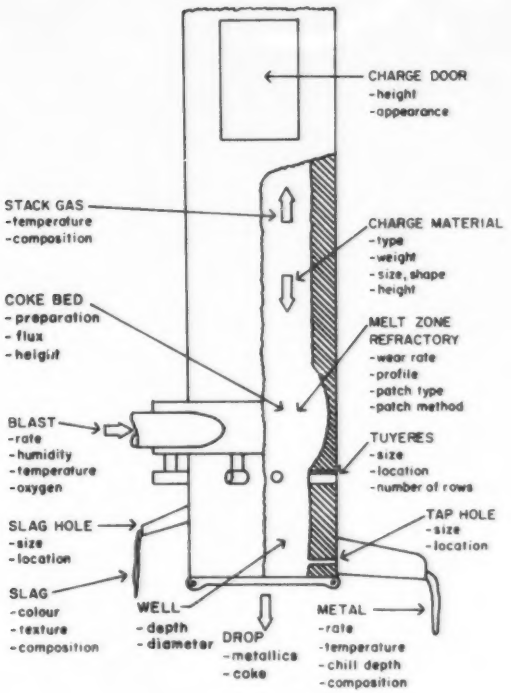

Fig. 1. Schematic summary of cupola test parameters. (neg 4655)

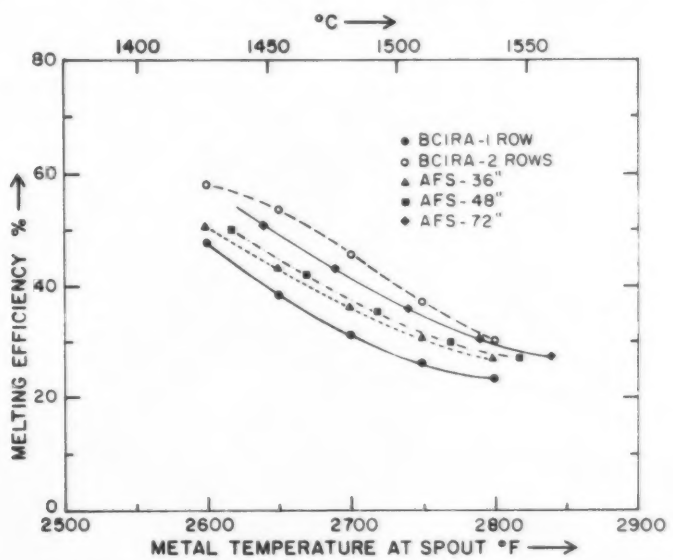

Fig. 2. Relationship between metal temperature and melting efficiency for selected cupolas. (neg 4573)

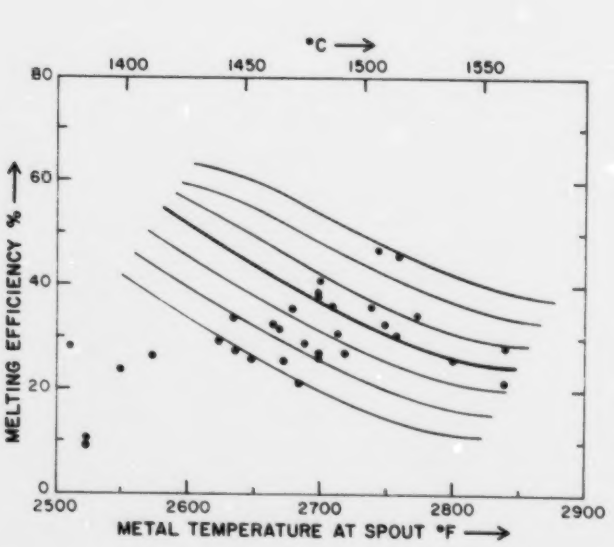

Fig. 3. Data points for survey cupolas superimposed on temperature normalization curves. (neg 4575)

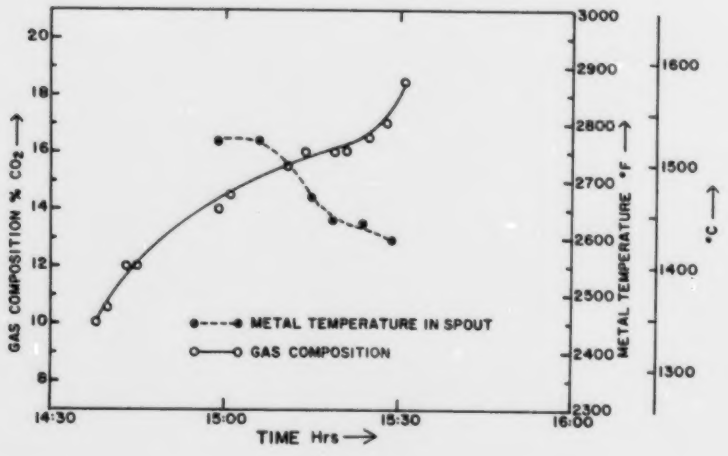

Fig. 4. Stack gas CO_2 content and metal temperature for a small cupola whose coke bed decreased rapidly with melt time. (neg 4574)

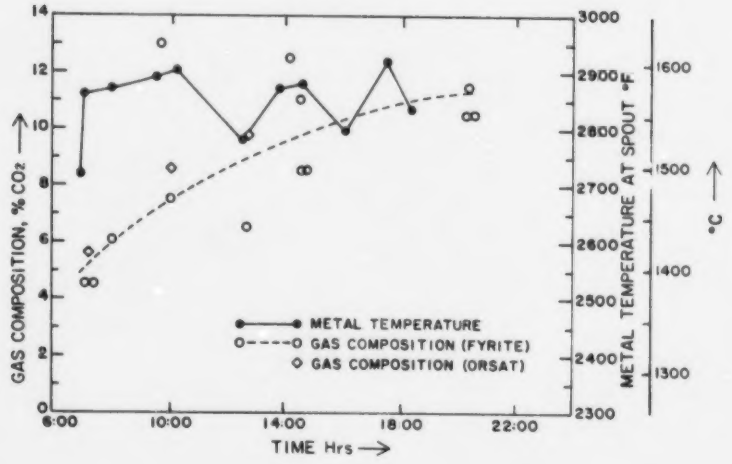

Fig. 5. Stack gas CO_2 content and metal temperature for a large cupola whose coke bed decreased slowly with melt time. (neg 4577)

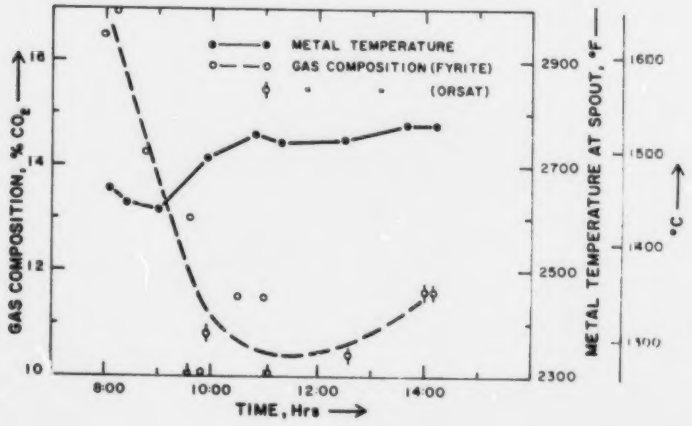

Fig. 6. Stack gas CO_2 content and metal temperature for a cupola whose coke bed increased with melt time. (neg 4572)

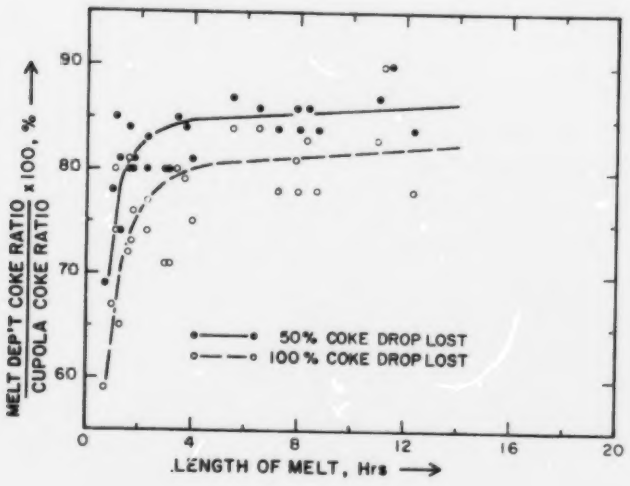

Fig. 7. Relationship between melting department coke ratio and cupola coke ratio. (neg 4578)

CASE NO.	MELT TIME h	MELT RATE Tonne/h (Ton/h)	COKE DROP kg (lb)	CUPOLA M.E %	CUPOLA M:C RATIO	MELT DEP'T M:C RATIO	MELT DEP'T COST $/Tonne ($/Ton)
1	8	11·4 (12·5)	1270 (2800)	62	13·8	11·3	20·44 (18·58)
2	4	4·3 (4·7)	320 (700)	52	11·6	9·4	24·57 (22·34)
3	1·4	3·5 (3·9)	250 (550)	25·5	5·7	4·5	51·34 (46·67)
4	8	11·4 (12·5)	1270 (2800)	57	12·5	10·3	22·43 (20·39)
5	4	4·3 (4·7)	320 (700)	44	9·6	7·9	29·24 (26·58)
6	1·4	3·5 (3·9)	250 (550)	29·5	6·5	5·0	46·20 (42·00)

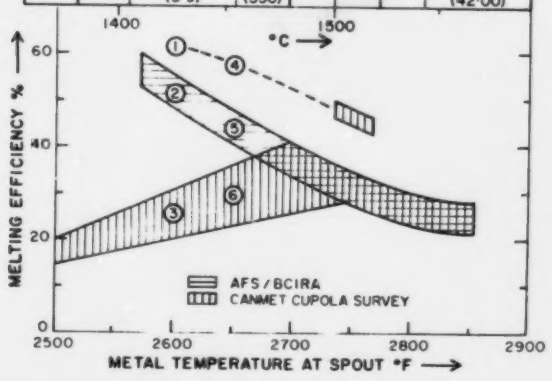

Fig. 8. Schematic diagram showing three groups of cupola performance and typical coke costs for each group. (neg 4576)

APPENDIX. Summary of melting performance and design and operating characteristics.

Fdry No.	M.E. %	Latent heat %	Sensible heat %	Shell losses %	Metal temperature at spout °C (°F)	Carbon equiv. initial (final)	Slag conditions B	Slag conditions % FeO	Time hrs	Cupola melt zone diameter cm (in)	Cupola height cm (in)	Tap type	Control	Aids	η_v	Specific blast rate $Nm^3/m^2/min$ (SCFM/ft^2)	Specific melt rate tonnes/h/m^2 (tons/h/ft^2)
5	45.5	29.1	7.0	12.8	1515 (2760)	1.80 (3.10)	N.D.	N.D.	8.7	152 (60)	457 (180)	C	1,2,3	4,6	54	66 (215)	6.6 (0.67)
2	46.5	32.4	8.6	12.6	1507 (2745)	N.D.	0.61	1.5	8.0	122 (48)	561 (221)	C	1,2,3	5,6	50	85 (278)	9.1 (0.93)
15	34.4	34.6	17.0	8.4	1524 (2775)	N.D.	0.66	0.8	12.3	130 (51)	414 (163)	C	1,2,3	5	47	103 (338)	8.3 (0.85)
27	28.2	45.0	10.1	12.2	1560 (2840)	4.05 (4.35)	0.85	0.8	11.5	198 (78)	640 (252)	C	1,2,3	4,5,7	28	63 (205)	5.1 (0.52)
4	41.0	21.6	5.9	25.1	1482 (2700)	4.10 (4.00)	0.79	1.4	7.2	152 (60)	701 (276)	C	1,2,3	4,7	66	75 (247)	6.4 (0.65)
19	35.7	36.6	11.5	10.2	1504 (2740)	3.95 (4.05)	0.81	1.5	16.0	137 (54)	670 (264)	C	1,2,3	4,5,7	43	82 (270)	7.0 (0.72)
15a	32.5	34.0	14.4	13.6	1510 (2750)	N.D.	0.66	0.8	11.0	130 (51)	414 (163)	C	1,2,3	5	48	127 (418)	9.3 (0.95)
6	38.2	13.2	18.1	23.0	1482 (2700)	N.D.	N.D.	N.D.	5.5	76 (30)	343 (135)	C	3	5	80	119 (390)	9.3 (0.95)
9	37.8	23.3	10.8	20.0	1482 (2700)	4.45 (4.35)	0.75	2.6	1.3	81 (32)	488 (192)	C	1,2,3		65	128 (420)	9.6 (0.98)
14	36.0	23.6	18.7	16.2	1488 (2710)	4.35 (4.15)	0.60	2.4	6.5	81 (32)	472 (186)	C	1,2,3		65	120 (395)	8.6 (0.88)
23	30.4	29.4	14.8	14.6	1513 (2755)	3.95 (4.15)	0.51	3.0	4.0	97 (38)	559 (220)	C	1,2,3		56	77 (252)	4.8 (0.49)
28	26.3	43.5	11.1	13.7	1538 (2800)	3.90 (3.80)	N.D.	N.D.	8.3	84 (33)	546 (215)	C	1,2,3		37	125 (410)	7.2 (0.74)
16	35.4	27.5	10.6	21.3	1471 (2680)	3.85 (4.05)	0.62	3.2	3.4	107 (42)	518 (204)	C	1,2,3	5	60	114 (375)	8.6 (0.88)
21	30.7	37.4	6.6	19.4	1491 (2715)	4.45 (4.25)	0.75	3.0	7.9	91 (36)	503 (198)	C	2,3		44	76 (249)	5.3 (0.54)
29	21.4	35.6	13.5	23.6	1560 (2840)	4.25 (4.15)	0.66	2.0	3.1	86 (43)	384 (151)	C	3		48	101 (330)	4.4 (0.45)
24	26.8	42.3	9.1	16.7	1493 (2720)	4.20 (4.10)	0.44	3.4	3.7	102 (40)	437 (172)	C	2,3		38	74 (243)	4.5 (0.46)
22	31.8	35.5	8.7	17.6	1515 (2760)	N.D.	0.59	1.6	2.3	81 (32)	N.D.	C	1,2,3		47	96 (314)	6.8 (0.69)
10	32.3	17.7	21.3	22.6	1463 (2665)	4.45 (4.35)	0.34	7.5	1.6	91 (36)	485 (191)	C	2,3		74	102 (334)	6.1 (0.62)
26	28.9	28.9	19.6	17.3	1477 (2690)	4.35 (4.25)	0.67	1.0	3.0	76 (30)	259 (102)	I	2,3		57	81 (265)	4.8 (0.49)
12	26.9	19.7	22.8	26.9	1482 (2700)	4.60 (4.50)	0.66	4.6	1.6	94 (37)	320 (126)	C	1,2,3		71	135 (444)	6.9 (0.70)
8	26.1	33.5	19.5	18.5	1482 (2700)	4.15 (4.05)	0.05	19.0	0.7	71 (28)	455 (179)	I	2,3		51	129 (422)	7.0 (0.72)
7	33.8	22.6	19.2	20.4	1446 (2635)	4.50 (4.40)	0.71	2.8	2.3	91 (36)	323 (127)	I	2,3	5	66	98 (321)	6.9 (0.71)
13	25.7	22.8	24.1	23.7	1468 (2675)	4.15 (4.05)	0.58	7.0	1.0	81 (32)	472 (186)	I	2,3		67	92 (302)	4.6 (0.47)
3	26.0	29.6	10.1	27.1	1454 (2650)	4.95 (4.65)	0.51	5.7	1.2	76 (30)	366 (144)	I	2,3		55	115 (376)	6.5 (0.66)
10a	27.6	34.2	19.3	16.5	1449 (2640)	4.40 (4.30)	0.34	7.5	1.8	91 (36)	485 (191)	I	2,3		50	94 (308)	5.8 (0.59)
20	29.1	30.4	12.1	20.7	1440 (2625)	3.20 (3.90)	0.88	5.4	1.7	91 (36)	457 (180)	I	1,2,3,	5	55	92 (300)	6.2 (0.63)
1	21.2	32.4	24.1	16.9	1474 (2685)	4.55 (4.45)	0.63	1.5	1.1	86 (34)	569 (224)	C	2,3		55	129 (422)	5.8 (0.59)
17	28.7	30.4	9.8	25.3	1413 (2575)	4.05 (3.95)	0.23	8.7	4.2	61 (24)	439 (173)	I	3		55	88 (287)	5.4 (0.55)
18	25.7	11.6	31.9	29.3	1400 (2550)	4.20 (4.00)	0.15	10.0	1.0	76 (30)	343 (135)	I	-		83	118 (387)	5.6 (0.57)
11	28.1	16.7	16.1	31.2	1380 (2515)	3.95 (3.85)	0.47	7.9	3.3	86 (34)	371 (146)	I	3		76	80 (263)	4.4 (0.45)
25	10.7	36.8	26.9	24.7	1385 (2525)	N.D. (4.25)	0.01	12.4	1.1	86 (34)	259 (102)	I	2,3		47	127 (415)	3.0 (0.31)
30	9.2	60.3	17.0	12.4	1385 (2525)	N.D. (4.20)	0.42	2.1	2.0	76 (30)	198 (78)	I			14	85 (277)	2.2 (0.22)

Legend : 1, Blast control; 2, Metallic charges weighed; 3, Coke weighed or charged by volume; 4, Hot blast; 5, Oxygen enichment; 6, Divided blast; 7, Liningless, watercooled.

η_v = Combustion Ratio = (% CO_2) ÷ (% CO_2 + CO)

B = Basicity Ratio = (% MgO + % CaO) ÷ (% SiO_2)

C = Continuous Tap

I = Intermittent Tap

A REVIEW OF FOUNDRY ENERGY CONSERVATION AT GM OF CANADA

by

D. Braithwaite

While the title of this presentation is probably not of the attention-grabbing kind, it is, I hope, a reasonable description of its contents. An overview will be given of 6 energy cost saving activities at GM of Canada'a metal casting plant in St. Catherines, Ontario. The activities in question have been selected for variety. They differ greatly in their degree of technical sophistication and in the capital required for implementation.

To provide a setting for the items to be presented, some knowledge of the nature of the GM of Canada operation is required. We are an automatic foundry making very high volumes of grey and nodular iron castings by automated methods. Poured tonnage can exceed 3,000 tons per day, of which about 2/3 is grey iron.

We pour iron melted by both cupolas and coreless prime melters into high pressure green sand moulds in large flasks. Cores are made by hot box, cold box and shell core processes. Shot blasting predominates as the cleaning method, continuous helical mills being used wherever practical.

Our formal energy conservation programme started in 1974 after the first oil embargo and has shown a 22% energy use reduction to the end of 1979. This reduction is based on savings which are adjusted for level of operation, weather effects and changes in the size of the plant. All projects and activities are examined for energy impact and rigorously justified on an economic basis. Monthly staff meetings and regular reports to corporate head office help motivate the programme.

The corporation's concern for energy conservation is reflected in the very highest levels of the administration and increased energy efficiency is seen as a substantial benefit to the corporation and to our society. Energy management reports are couched in mega BTU's for the most part so that price fluctuations and rate structures cannot obscure the results in terms of fuels and utilities.

The St. Catherines foundry uses about 35% of GM of Canada's total energy requirement so that is is reasonable to say that as the foundry goes, so goes the entire division.

I will present a cross-section of projects large and small, in case history form. Not all will be relevant to every foundry, but all are, I hope, capable of being thought-starters for any foundryman. A thought-starters are not to be lightly regarded, since a common experience is that after your foundry has done the easy, obvious, high rate-of-return energy savings items, ideas become the scarest and most precious commodity. Then thought-starters become very valuable.

The first case history is an engineering or technology intensive modification which was carried out on 3 gas-hungry cupola emission control systems. The cupola gases are taken off below the charge door at a bustle and ducted to a nearby combustion chamber which is a large, unlined, water-wall cooled vessel. In this vessel, additional air, which we termed secondary air, entered low down, tangentially to the vessel wall and 3 very large gas burners ensured combustion of the carbon monoxide to carbon dioxide by holding the vessel at a temperature of 1400°F minimum. This assured us that no accumulation of explosive CO could occur, but given the large volumes of air and gasses handled through the system and thus the heat carried out, gas use was very high. A further problem was that poor mixing of the secondary air caused "puffing" through uneven burning, and the resulting pressure fluctuations had an adverse effect on burner stability.

The corrective action taken was to install an elaborate wind-drum which introduced the secondary air at high velocity, with a vigorous swirling action, at the point where the gases entered the combustion chamber. With good mixing thus ensured, three smaller burners were used to ignite the mixture only a couple of feet after the air injectors, just at the exit from the wind-drum into the vessel. The wind-drum required was a geometry teacher's joy and a tinsmith's nightmare, especially as it was also designed to provide an air-pressure sealed sliding expansion joint in the duct and eliminate a troublesome stainless steel bellows.

The burners used were of a very high velocity, high excess-air type with milk bottle tiles that, we were sure, could withstand vessel pressure changes. In a sense, they were in effect pilot burners and the fuel which heated the vessel was the CO in the effluent stream.

The results obtained were savings of over 60% in gas usage and a reduction in system downtime. The modification was fairly costly and required considerable engineering work.

The second item for your consideration is a simple, inexpensive waste heat recovery concept that was installed on several hot-blast cupolas. It provided a means of recovering most of the energy waste occurring from venting the hot blast heater output to relief.

Because our cupolas operate to supply iron to automated moulding lines which experience interruptions in operation from time-to-time during a shift, they spend significant time with the hot blast off the tuyeres. During these periods, the 900 to 1200°F blast air is vented outside the plant, to "relief". This is necessary because the blast heat exchanger must be protected from thermal shock, thus excessively low air flow and rapid temperature changes must be avoided. The relief blast air is clean, high temperature air requiring only dilution with outside air to useable temperatures for use in building heating.

This relief air is now diverted and diluted abcve the roof line and ducted to the intake plenums of air make-up units. These units are each equipped with outlet duct thermostats controlling the steam or gas delivery to that level required to hold the set temperature. When the incoming outside air is warmed by the addition of recovered diluted relief air, the unit's existing control system alters the firing rate to save fuel while maintaining a uniform air delivery temperature. The relief air diverter duct is, of course, closed in summer.

The result obtained is a small reduction in heating energy use in return for a small capital outlay. The method used for dilution and diversion is simple and maintenance free. If you wish to try the idea be very sure that dilution to a manageable temperature is failsafe - our first attempt caused a minor building fire and buildings make very expensive fuel by any method of evaluation.

For the next item we must take a large step forward in sophistication and cost. The GM of Canada metal casting plant makes use of what we term UMACS - the utilities monitoring and control system. This is an automatic control system governing the run-time of all building heating and ventilation equipment. The system is technically complex, had a high initial cost, is

expensive to operate and maintain, but offers very substantial savings for a large plant with extensive exhaust systems.

Our plant, which has about one million square feet of floor space, has approximately 6 million cubic feet per minute of exhaust which, in winter, must be replaced by air which is heated by natural gas or steam. We make about 6 air changes each hour when all systems are operating. Previous to installing the UMACS, this equipment was very difficult to control properly manually because many units were very small and control was dispersed over hundreds of locations, some of them out of the way on remote platforms. Many employees did not know precisely which units served various work area and would start several fans in order to be sure of exhausting or heating one location. Air diffusers were constantly being tampered with, causing air volume and air delivery temperature problems on air make-up units. Small stack fans were often overlooked when shutting a facility down because their horsepower is small and they were felt to be very insignificant. This ignored the fact that while the fan energy is small, the cost of heating air to replace what the fan expelled is not small, especially in view of a stack fan's ability to exhaust six times as much air per horsepower as a dust collector. Thus, heating costs incurred in operating a 30 HP stack fan equal those for a 200 HP wet collector.

UMACS controls all heating and ventilation equipment to the extent of stopping and starting it and monitoring it for adherence to a pre-entered schedule. The major element in the UMACS is an IBM system 7 computer. It is manned around the the clock by operators who are building maintenance tradesmen. These men enter the desired operating schedules and can remotely control individual units for unscheduled operation at the request of people working in the unit's area. Equipment operating schedules are entered by production facility, such as a moulding line, rather than by unit, thus saving time in schedule loading. Each piece of air handling equipment can be given a settable time offset from the operation shift start and end times. For instance, cooling hood fans need not start until, say, 10 minutes into a shift but must continue for about 20 minutes after its end, that is to say, until the last moulds poured stop smoking. UMACS can take care of this requirement.

Because direct gas fired air make-up units have a poor turn-down ratio and don't throttle well for low heating requirements, UMACS was programmed for a feature which cycles these units on and off at their normal

firing rates in response to plant temperatures. This mode of operation is used on weekends, and allows plant temperatures to be reduced without altering the individual outlet thermostats which control the firing rates.

The installation of UMACS has resulted in a warmer plant during operating hours, a cooler one when not operating, a major reduction in the running time of our exhaust systems and savings in fuel on the order of $0.5 million per year. Capital cost was high and operating expense is considerable, but payback is very satisfactory, and returns improve yearly as fuel costs climb.

The fourth item is a simple operating procedure change made to lessen coke breakage and thus reduce fines loss and reduce coke usage by improving coke quality. I have been told that size is an important factor in coke quality, and "the larger the better". Our coke is unloaded from hopper rail cars and carried by a system of rubber belts to the cupola coke bins into which it drops from the belt. This operation was done on the day shift only and the bins were often quite low by the next morning, giving a long drop from the belt to the bottom of the bin. The result was, of course, breakage of the coke lumps more or less proportional to the distance which they fell.

The change made was simply to unload coke in the morning and then again on the evening or afternoon shift, keeping the bins topped up and reducing the fall from the belts to the top of the coke lying in the bins. Naturally, this gives less breakage, less fines and larger coke in the cupola.

The savings created are difficult to measure given the fluctuation in coke size and quality as delivered, but the coke fines recovered have been reduced. The percentage saving is undoubtedly small, but with coke use on the order of 6 to 8 thousand tons per month, even small percentages mean appreciable amounts of money. And the prices of implementation is right - no capital cost, no engineering and no waiting for equipment.

The activities described so far all save energy and by this reduce energy cost. There are, however, activities that save energy cost without reducing energy use. I have included one of these in this review and wish to make the distinction clear. Some examples of energy cost-saving activities that reduce energy cost while not reducing the actual BTU's or energy units consumed, are where conversion is made to a less expensive energy form with some loss of efficiency in order to gain a net cost reduction, or where a user takes advantage of a utility rate structure as can be done with

electrical peak power demand reduction. For instance, it can be good business to change from electrical heating to gas heating in order to benefit from the 60% reduction in cost per BTU, even if more energy is used due to the lower efficiency of gas heating. The efficiency loss can be more than offset by unit cost reduction, leading to a net savings. Similarly, electrical power peak reduction can decrease your hydro bill while allowing you to use the same amount of energy.

We will now consider such a system. Four large, 55 ton coreless induction furnaces were brought under peak power control by a relatively simple relay-logic system. The maximum rate at which electrical power is drawn from the utility has been reduced, thus reducing the electricity bill which is comprised of peak demand changes and energy consumption of kWh charges in approximately equal portions. KWh consumption is determined by the tonnage melted, since each ton of iron requires a certain kWh to reach a designated temperature. This makes the kWh consumption very difficult to reduce - but not so for peak demand.

The furnaces normally operate three at a time, pouring in relays to provide a continuous delivery of up to 50 tons per hour. Initially, they were being put on "melt" power of 15 megawatts each when they were ready, as soon as they had been charged, rather than when required. The demand charts, recording kW load against time, showed that the top 5 or 6 mW of the range were being used, accumulatively, only about 2 or 3 hours in each monthly billing period. These few hours were costing tens of thousands of dollars each month, so that no one could afford to buy the iron melted in that time.

One of our maintenance electricians who carefully observed the electrical melt operation conceived of a simple demand limiting strategy that would be inexpensive to install, and which would give minimal interference with the flow of iron to the moulding line. A limit switch in a kW demand slave recorder detects when the maximum demand set point has been reached, and automatically restricts all furnaces to low "hold" power. All, that is, except the one which was first to go on melt power. The reason for this strategy is that the first of the furnaces on melt would naturally be the first finished, and thus the next furnace to pour - we dubbed it the "lead furnace". By making the lead furnace immune to interruption by peak limiting controls, we are assured that the very next heat of 15,000 lbs will not be delayed. Power to all furnaces on melt is restored when the thermally

delayed peak meter falls off 4 or 5 mW, at which time the meter starts its rise toward the set point again and the cycle repeats. The result is a saw toothed line on the demand chart with the points at the set maximum and the bottoms of the notches about 4 mW lower. The furnaces have SCR semiconductor power supplies which allow frequent on/off cycling without incurring penalties in maintenance, as there is no wear factor or life span in terms of number of cycles or operation for these units.

The loss in tonnage throughput for the furnaces is well under one (1) percent because the operation to which the furnaces feed is subject to frequent but brief interruptions which allow the melt facility to catch up before the effect of holding back a non-leading furnace can reach the pouring operation. The bank or "float" of ready-to-pour iron in the hot metal transfer system helps smooth out the melting interruptions caused by peak limiting.

The result achieved is savings of hundreds of thousands of dollars per year for a very modest investment, and minimal interference with mould counts. There is a further, external benefit to Ontario Hydro in peak demand reduction if it is practiced generally by subscribers. Hydro's capital investments can be reduced if demand is made more constant, and less "peaky". The peak control panel itself consists of a few control relays and the addition of a limit switch to a previously existing slave kW recorder. The powers of observation and the ingenuity of a tradesman showed that peak demand control, when it is done by manipulating one large electrical load or facility, does not <u>necessarily</u> have to be complex or expensive. If a simple strategy can be defined, the control can be simple, inexpensive and maintainable.

The final case history is one involving personnel training. In using natural gas, energy use is minimized and wastage reduced by maintaining the combustion equipment in a proper state-of-tune. That is to say, keeping the correct air-to-gas proportions at all firing levels of a combustion system will lead to minimum gas use. Keeping this good state-of-tune requires trained maintenance pipefitters.

At the outset, few of our pipefitters had adequate knowledge of the operation and adjustment of gas burning equipment. In a foundry, this equipment is extensive and sophisticated, supplying, as it does, the energy for blast heaters, core machines, ovens, emission control units and heaters. In our plant, data sheets for burners and other gas train items were available,

but the information had not been refined and made specific to the individual systems. Our first step, then, was to develop system set-up and data sheets with step-by-step procedures for each and every system. Included in the information are all the necessary pressure and flow settings for tuning. All systems were provided with test points and orifice plates required to do a comprehensive check and calibration. The second step was to have the engineer responsible for combustion systems give practical training courses to the pipefitters on system set-up and fault diagnosis.

Once again, savings are difficult to evaluate accurately, but in a plant situation where a 5% improvement in natural gas combustion efficiency will save about $20,000 per month, even small improvements in performance are worth pursuing. Even in the absence of energy savings, benefits from improved equipment safety and reduced equipment downtime and maintenance costs will justify tradesmen training. If a foundry has a resident engineer competent in combustion work, a programme such as that described can be fitted into the engineer's responsibilities at no additional outlay.

Energy conservation projects, as these six samples have endeavoured to show, can cover the full range of levels of sophistication, capital expenditure, operating cost and return on investment. While heavy capital spending and acceptance of technical complexity may be necessary to fully exploit your foundry's energy conservation potential, there are almost certainly simple, low cost measures awaiting implementation. For many of these vital requirements are the intimate knowledge that all good foundrymen have of their plant's operation and idiosyncracies and an alertness to the opportunities that knowledge will offer. Such measures are perhaps the best and most satisfying of all energy conservation activities because they return so much for so little effort.

ENERGY CONSERVATION IN CANRON'S FERROUS FOUNDRIES

by

J.C. Hungate

Energy conservation is a two step process - identification and execution - and the execution usually involves capital expenditure. On a simple walk through any foundry, one is continually exposed to what may be regarded as wasted energy practices, or it may be a necessary evil to overcome some other built-in problem.

In general, compared with other types of heavy industry, there are relatively few major pieces of equipment in the foundry that require large inputs of energy - but those few items may represent more than 80% of the total plant energy load.

Generally speaking - apart from lighting and ventilation - it has become a habit to overdesign when writing up specifications for foundry equipment. Most foundries have poor lighting (but improvements are on the way), or are inadequately ventilated - as is evidenced when standing in any door opening. The inrush of air created by the negative pressure conditions within most shops is only slightly less than overwhelming.

In Ontario - part of the earlier safety legislation was directed towards adequate exhausting of the foundry buildings. You may recall - "2,500 CFM of air exhausted for each ton of metal poured in an 8-hour period, and 500 CFM for each employee". This can amount to a lot of CFM's and a similar amount of air - heated or otherwise - must be introduced into the shop in the correct manner to eliminate draughts and to allow the localized fume exhaust systems to operate properly.

There are many areas where heat can be reclaimed and just as many suppliers selling heat transfer and recovery equipment. In several cases, the cost of capital equipment far exceeds any potential savings and cannot be justified. We at Canron have looked into, and discarded, a number of ideas for energy savings and in other instances have been pleased with the results. After all - there are many BTU's of wasted heat energy going up the stacks of cupolas or down the drains as cooling water.

To list some items in a typical foundry with potential savings -

- Space heat recovered from the roof monitor area - and there are several methods of doing this, using fans or fresh air ducts.
- Savings in heat-up time and the BTU's required when using a low mass fibrous insulation in heat treatment ovens in place of the more dense refractory brick linings.
- Trapping and recirculating heat released from a loaded car of castings after removal from the heat-treat oven.
- Covering of heated dip tanks when not in use.
- Preheating of combustion air using a heat exchanger and stack hot exhaust gases.
- Recovery of heat from cupola, etc., cooling water.
- Reduction in electrical energy usage with reduced wattage lamps and ballasts and the newer more efficient high intensity discharge lamps.
- Energy wasted in the making of scrap castings.
- Coke savings by converting to divided blast in the cupola.
- Coke savings from oxygen enrichment.
- Savings from control of electrical power usage - both demand and energy components - through power factor correction, maximum demand control, utilization and scheduling major energy items, especially electric melting.
- Selection of environmental equipment with concern for energy usage.
- Maintenance of insulation and refractory in ovens.
- Maintenance of buildings, such as ill-fitted doors and windows.

Environmental

In recent years the collection of particulate matter from foundry plants and processes has been a major energy usage and cost item on foundry engineering programs and budgets. The requirements for emission collection have been partly legislated and partly the desire of plant management to operate in the best manner possible in relation to its neighbours, employees, and the public at large.

Emission control equipment is a major item on the energy budget in any foundry. Generally electrically oriented, but in addition, there are the requirements for fuel burning equipment and water. Most of our foundries are equipped with emission collection equipment or systems on cupolas and

furnaces, mullers, shakeouts, sand conveying systems, casting cleaning equipment, etc.

And since it is mandatory to achieve a level of collection efficiency, the selecting of equipment becomes an exercise in comparing one type of collector to another so that we may obtain the desired efficiency but limit the capitalized amount and the operating costs.

When one analyzes the electrical demand load of a foundry - and the percentage of that load represented by emission control equipment - then the importance of proper equipment selection becomes a very high priority energy conservation issue. As an example of this, in three of the Canron foundries, the portion of the maximum electrical demand required by pollution equipment and systems is between 35 and 45% of the total plant demand load. Now - what easier way to conserve electrical energy than turning off the pollution control system?

In addition, there are gas-fired stack burners sized at a total of 26×10^6 BTU/h as part of the emission control systems.

Unfortunately, and realistically, the pollution control systems cannot be turned off - nor is it possible to switch this demand to the off-peak period of the operating day. Thus, it behooves us to control the installed systems at optimum efficiency and to design for new systems where the energy content is as low as possible.

One system, using a 1000 HP motor with an adjustable venturi wet scrubber, has in its control a peak load limiter operating between set points that ultimately control the hydraulically operated venturi and therefore the electrical load on the system's main exhaust fan. This allows the motor to operate at less than 1000 HP yet adequately control the scrubbing action through the venturi.

Control of stack burner natural gas volumes in cupolas can be partially achieved through burden depths and the size of charge door openings. Lowering of the burden depth results in better flames through the burden and hence an elevated temperature in the upper stack. Reducing the size of the charge door opening and amount of air drawn in by the emission control system also creates higher temperatures in the stack. Combining these features with sensors and gas flow control valves results in a decrease of natural gas volume demand. In addition, reducing the size of charging door openings

results in lowering the air volume required and a reduction in size of the exhaust fan and motor.

Selecting a baghouse over a high efficiency wet scrubber on a cupola could represent a reduction of several hundred HP. With present technology and equipment, we now realize that a baghouse with total electrical input of 300-400 Hp could satisfactorily replace a venturi wet scrubber with a total installed 1200 HP. This represents a saving of 800 HP and in addition, based on experience, would probably be a lower cost item to maintain. New filter fabric materials, used and tested over the past few years, have proven to be satisfactory. Fluorides in the charge make-up are a concern, but there are substitutes for fluorspar and the use of nomex bags in place of fibreglass has also provided an acceptable filter fabric.

Apart from cupola emissions, the collection of other foundry particulate emission can be improved - energywise - through the proper design of the collection hood at the source. By providing control at the source - not several feet away but as close as possible - results in controlling the emissions with less total air exhausted and hence less HP required. In addition, there are the benefits from a reduction in the amount of make-up air required.

The cost of an exhaust system is directly related to the amount of air exhausted - not necessarily to the percentage of contaminant in the exhaust stream - and the more the contaminant is diluted before reaching the exhaust hood, the greater is the required amount of energy and the number of dollars wasted.

In an emission control situation, it is beneficial to supply unheated make-up air at the proper location. This air can be introduced from a low powered blower or fan, drawn across the pollution source and immediately exhausted, allowing the exhauster to operate efficiently with an adequate supply of unheated air. Most foundries are plagued with negative pressure conditions because of the large number of roof exhaust fans, and any emission control exhaust system just adds to the problem.

Legislation decrees that a certain degree of efficiency be maintained in emission control systems. However, that extra little bit of efficiency in going from 90% to 95% or from 95% to 98% can represent a large increase in input energy requirements.

Apart from the control of emission source areas, make-up air is required for building ventilation. I can recall a wire products plant with process ovens where the roof exhaust conditions so overwhelmed the make-up ventilation air that the oven exhaust gases were reversed and drawn down the stack and into the shop.

A plant must have make-up air if exhaust systems are to operate properly - and heated make-up air is a costly item. In general, there is warm air at the upper level of most buildings. The temperature gradient increases approximately 2% per foot of height in buildings. Thus, a 30 foot high building with 60°F at floor level could be 90°+ at the ceiling. Taking advantage of this heat can be accomplished in a number of ways and the method we like is to introduce fresh outside air by ductwork at the upper level. This fresh air works its way down by gravity through the make-up air. Although it has not been introduced at the pollution source, this make-up air does relieve the negative pressure condition in the shop and allows the exhaust systems to operate more efficiently.

Using this principle, a recent installation of 70,000 CFM was installed at a cost of $0.25 per CFM and supplies unheated make-up air without discomfort at the worker level. A similar sized heated unit, gas fired with ducting would cost in excess of $1.00 per CFM installed and in addition would carry the burden of fuel costs.

Where make-up air is not required, such as warehouse or service buildings, the heat trapped at the ceiling can be driven down to floor level through the use of ceiling fans.

It requires approximately 1 BTU to raise the temperature of 1 CF of air 50°F, and in the course of our winters, this can represent a major item of energy usage. Compared with a direct fired make-up air heater, the ducted fresh air unit mentioned earlier supplies tempered make-up air at a saving of approximately 4×10^6 BTU/h representing $20,000 per year.

Fresh Air Make-Up

Taking advantage of this upper level heat has additional benefits. The negative pressure within the shop has been reduced, the temperature throughout the building is more uniform, the atmoshphere at the ceiling level is improved, there are no severe draughts, and the heat losses through the roof are reduced.

Compressed Air

When I first started to prepare this paper, I was aware of a few shortcomings in areas where we should be benifitting from energy conservation, but were too slow in putting the project into motion. Trade journals presented several articles expounding the benefits of energy conservation, some of which have been mentioned in the past two days.

Compressed air is one such topic. We need this facility for many of the foundry industry operations but it appears that most employees treat it as a free utility. An air compressor is one of the least efficient machines - approximately 20-25% of the power input goes into the compressed air and the remainder as waste heat - yet the compressed air is often misused and the heat is seldom reclaimed. In fact, the cooling water is generally dumped down the drain or it may be used as clean make-up water in some other system.

Leaks in a compressed air distribution system are often ignored, perhaps because they are not detected while the plant is operating and noisy, and the compressors may be shut down during the off shift. But, a small leak can result in continuous demand on the compressor so that it never unloads.

Then again, there are different types of compressors, each with its own performance curve. For some models, the power requirement, when unloaded, is 40-50% of full load power, and others with an unloaded power requirement of less than 20%. This feature should be considered in any future acquisition.

But what about the 75% or so of energy that is wasted as heat? In many compressor rooms this heat is bothersome and is usually exhausted with the ventilation system. In one plant, where the compressors are grouped together, we exhaust this heat into the production departments during the winter months, and this has resulted in reducing the heating by 300,000 BTU/h.

The new types of air cooled compressors allow for improved heat recovery as space heating. Ductwork can trap and direct this heat to those areas where it is required.

How much compressed air is needed to operate a foundry? Who knows? But much is wasted. It is agreed that cylinders, air motors, hoists, transporting systems, baghouses, etc., all require compressed air and usually at 90-100 Psig. But what about blow-offs where velocity and volume are required but not high pressure - or combustion systems where a low pressure

blower is much more efficient - or the use of compressed air for cooling ladles? This last item - WELL!!!

Most compressors will give you between 4.5 to 5.5 CFM per HP. A $\frac{1}{4}$in. opening - be it a leak or an open nozzle at 100 Psig can demand 103 CFM from your compressed air system, enough to prevent the compressor from unloading.

At 5 CFM per HP, a $\frac{1}{4}$in. opening results in a flow volume of 100 CFM and electrical energy input of 20 HP. At todays costs, this represents approximately $1,100.00 per year on a one shift basis; and while a compressor at 100 Psig gives 5 CFM per HP, the low pressure blower at, say, 10 in. SP can deliver 500 CFM per HP. So if your plant is using compressed air to blow off patterns, sand, chips, etc., you may want to look into this operation.

Air Compressors

A 100 HP compressor generates about 280,000 BTU/h in addition to supplying ~500 CFM (the compressed air).

Therefore, 0.28 x $2.80 x 30 x 24 = $564 if all heat was reclaimed.

If a 100 HP air-cooled compressor's wasted heat was used for space heating - and if the compressor operated continuously - the cost of heating at $2.80/CFM could be reduced by $500 per month.

Since compressed air peak demand is usually sporadic - and lasts only for a limited period - sizing of compressors is important.

A 200 HP compressor designed to operate at 50-80% FL can effectively be replaced with 4-50 HP compressors. In this arrangement, one of the 50 HP units can serve as back-up for the other compressors operating only when demand peaks.

Todays compressors have controls that allow more efficient unloading and start-up operations.

Lighting

Energy savings with lighting installations can be a substantial part of the conservation program. For many years, industry has had to settle for poor efficiency light output in terms of lumens per watt in the use of incandescent, fluorescent, and mercury vapour lamps. Mercury vapour lamps were considered the best available for heavy industry plants - especially those with a dirty atmosphere. Recently, a new family of high intensity

discharge lamps have been developed, each with its own characteristics, and generally they are a means of reducing the electrical energy required to light a building to the recommended lighting level.

I am referring to the low and high pressure sodium, and the metal halide lamps.

Existing fluorescent and mercury systems have excellent potential for energy reduction with relatively minor expenditures. There appears to be innate reluctance in everyone to discard anything that still has some useful life, but replacing these types of lighting systems can be justified.

A mercury lighting system is no longer a viable option for industrial lighting, and is second only to incandescent lighting in high operating costs. It has become obsolete by combination of energy economics, and improvements in luminous efficacy, life, and lumen maintenance of the high pressure sodium and metal halide lamps. Although a mercury vapour lamp has a rated life of 16,000-24,000 hours, at the 16,000-hour mark it has lost approximately 50% of its initial lumen output.

There can be no justification for not replacing in incandescent lighting system in industrial areas; and there is scarcely any investment that will have a shorter payback period than the wholesale replacement of incandescent lighting systems.

The low pressure sodium lamp is possibly the most efficient light source known, but this advantage is offset by the fact that all of the light from a low pressure sodium lamp is emitted in the yellow portion of the light spectrum. Where colour is no problem, this lamp is an excellent source of light and can result in reducing energy input. Its mean lamp efficacy is from 122-164 with an average life of 18,000 hours and is available in low wattage sizes.

By comparison, the H.P.S. is second with mean efficacy of 75-127 and metal halide third with 62-92. These latter two types have a rated life of 24,000 hours respectively.

We, at Canron, are currently on a lighting improvement program. In some areas, we are replacing M.V. with H.P.S. fixture for fixture, and in other areas, we are using fewer H.P.S. fixtures with improved lighting levels. By replacing 3 M.V. fixtures with 2 H.P.S. fixtures, the lighting level is almost doubled and simultaneously the energy input is reduced by one third.

There are retrofit options for some types of fixtures where special H.P.S. lamps have been designed to operate with mercury ballasts. Although these retrofit lamps produce substantial savings in lumens per watt, they are generally more expensive and have shorter life than the standard H.P.S. lamp.

Divided Blast - Cupola - Coke Savings

A few years ago, before the energy crunch, Canron decided to convert the two 48 in. - 10 ton per hour acid lined cold blast cupolas to the, at the time, new divided blast design with two rows of tuyeres. In our installation, the main blower pipe was divided into two separate mains each with its own flow control valve and instrumentation. The original set of tuyeres were left as is and the second row installed on staggered centres 36 in. above the original row. The tuyere diameters were reduced in size to increase the penetration and reduce the burn-out.

The arrangement resulted in raising the coke bed by approximately 3 feet and using 3,650 lbs of bed coke instead of the 2,600 lbs used in the single row operation.

However, the divided blast set-up permitted us to drop from 200 lbs of coke per split to 140 lbs. At the same time, the metallic charge was raised from 1,800 lbs to 2,000 lbs.

There have been no problems with chemistry changes caused by switching to divided blast. Total carbon remains the same and silicon recovery is very similar.

The amount of coke saved is approximately 750 tons per year representing $130,000.

We have since converted one other cupola with a melt rate of 18 tons per hour and have obtained corresponding savings.

Considering splits only and not bed coke - with the two 48 in. cupolas where we formerly operated at a metal to coke ratio of 9:1, we now operate at 14.3:1.

Oxygen Enrichment

In some installations, oxygen enrichment can be a means to reducing coke usage, and benefits ranging from 25% to 40% coke savings have been reported for 2% oxygen enrichment. With the divided blast system and the high metal to coke ratio, we have found that the coke savings from oxygen

enrichment are insignificant. However, several other benefits from this principle are realized. Among these are faster temperature pick-up both at start-up and following a break period and a more fluid slag resulting in the use of less fluorspar and limestone.

Heat Treat Ovens

Redesign of heat treat ovens has resulted in improved energy efficiency. Upgrading of gas burners and changing the firebrick lining to ceramic fibrous material has been completed in two of Canron's heat treat ovens. The new light-weight lining has low thermal conductivity, a high degree of radiant reflectivity, and is impervious to thermal shock. This material with its low heat storage properties - about 1/7th that of comparable fire-brick lining - allows for shorter start-up time and better turn-around cycle. With fewer burners for the start-up part of the cycle and shorter cycle, it is estimated that savings in fuel are 20%.

Most heat treat cycles include removing the load from the oven at some point in the cooling cycle. The heat from the carload of castings is usually allowed to escape to the ceiling and disappear as heat loss. We hope to trap this heat in some manner by hooding and convey it by blower to an operations area as space heating.

Energy Wasted in Scrap Castings

It would be nice to say that Canron does not have any scrap or defective castings - nor for that matter, does any other foundry. But there are defects and each one represents energy waste. Apart from the thermal energy - approximately 500 kWh per ton - to melt ferrous charge material, there are many additional hidden energy costs in some form or the other:

- Chasing, location and transfer of patterns to the production area and returning to storage.
- Lost cores and moulding cost.
- Metal loss - estimated at 6-7%,
- Pouring, shakeout, conveying, and cleaning.
- Metal testing, analysis and laboratory work.
- Inspection.

It seems that the energy wasted is much more than the fuel for conversion.

Electrical Energy Control

Depending on where you are located, monitoring and control of your electrical demand and energy usage may offer better dollar savings than many other energy conservation systems.

Hydro billing in the larger industrial areas is generally a set amount for each kilowatt of demand or 90% of kVA of demand, whichever is the greater, and an additional stepped energy rate of so much per kWh in three steps. The first two steps of the energy rate structure are usually at 100 x demand multiplied by their respective rates and the third step is the remainder of the months kWh at the lowest rate per kWh.

As an example for the Hamilton area, at a first glance at the hydro bill, the demand in this rate structure appears to be $1.55 per kW of demand. But since the first two steps of the energy portion of the bill contain a demand component, the actual demand cost is $4.80 per kW.

The utility company's demand meter usually records energy usage on a 15 minute interval and the average for that interval becomes the demand. The energy usage is integrated over the 15 minute period.

As an example, if a demand of 2,000 kW was maintained for 7.5 minutes of the interval - and zero demand for the remaining 7.5 minutes - the demand seen by the demand meter would be 1,000 kW.

The demand charge is based on the highest demand recorded for any demand interval in the billing period - usually one month.

If the load factor - or utilization factor - is low, say less than 70%, this usually indicates that controlling maximum demand can be beneficial to the cost of electrical power. Load shedding devices, tied in to non-essential loads, will help to level out the peak demand on the utility system when the demand rises to the pre-established desired peak. And for each kilowatt of reduced demand there is a monthly saving of $4.80.

One consideration that could be given to reducing demand costs is to balance the operating schedule over a 24 hour day instead of 8 hours. This is not always possible with the melting capacities of existing cupolas, but proper sizing and controlling of the melting rate of induction furnaces over a longer day can represent respectable savings.

Since the peak demand is set for each kW or 90% kVA, there is a penalty whenever the power factor is below 90%. Hence, power factor correction can be an extra saving.

Earlier, it was stated that it is a habit to overdesign for foundry equipment. This is especially true for some electrical drives where the motor may be oversized. Operating an induction motor at less than full load usually results in poor power factor. Correcting the power factor to 90% and reducing or eliminating demand penalty can usually be justified. This type of correction using capacitors has been completed at each of the Canron Foundry plants.

Capacitors, in effect, soak up lagging kilovars on a one for one basis. A 100 kilovar capacitor, for example, will cancel the effect of 100 lagging kilovars and release kVA on the system to carry useful loads.

If your electrical distribution system is overloaded, or if you require capacity for additional loads, correcting the power factor may release enough kVA to resolve the problem.

A new family of power factor motor controllers has appeared on the market. This controller apparently senses the low power factor resulting from a motor running at less than full load and through feedback continuously changes the voltage in accordance with the load factor of the motor. This action reduces the voltage and current under light load conditions and results in an operation at higher power factor. Reductions in both kW and kVA power provide significant savings in energy as well as demand.

Peak load can be controlled manually, but this relies on constant surveillance, and operator control and is not always satisfactory.

In one installation, where we have two 2,000 kW induction furnaces, we have installed a peak load limiter. This limiter receives its signal pulse from the utility demand meter and controls the peak load on the melting system during the 15 minute integrated interval to our desired peak limit. If in any 15 minute interval is a danger of exceding the desired peak, the power input to one furnace is reduced to 200 kW.

Since the melting system at this plant represents 85% of the electrical load, the benefits can be substantial.

Proper scheduling of charging and tapping can permit the use of this type of control since we establish the number of kWh required per 15 minute interval, and is most easily obtained when operating with furnaces that are near fully charged. Under these conditions, the electrical energy linkage is at an optimum and losses are reduced.

The cooling water associated with electrical induction furnaces can be used in a recovery system as space heating, depending on the system selected. This principle should be explored at the time of acquisition.

Demand - $1.55 per kW or .9 x kVA		
1st 100 x M.D.kWh.	@	0.039
2nd 100 x M.D.kWh.	@	0.0207
Balance kWh.	@	0.0136

Example of Demand Cost:

M.D. portion	$1.55/kW
Energy - 1st 100 x (0.039-0.0136)	$2.54
- 2nd 100 x (0.0207-0.0136)	$0.71
	$4.80

Recovery of Heat from Cooling Water

Where possible, we use cooling water in a multi use series manner. Clean warm discharge water becomes make-up in a second or third system such as emission control wet scrubbers or in the slagging system. When surplus clean water has been added to a wet scrubber, we have found that the system performs more efficiently and with less maintenance.

Possibly the best source of heat in any of our plants is the water used to cool the shell and tuyeres of the 102 in. water cooled cupola.

The flow rate is approximately 1,300 gallons per minute with a temperature rise in excess of 30°F. At present, there is an excess of fresh make-up water due to a balancing problem and cooling is by means of a cooling tower.

Recovery of this heat has been studied and preliminary designs prepared. But implementation is temporarily held pending other considerations. However, there appears to be a sufficient amount of heat available from this system to justify a heat recovery make-up air installation and in addition contribute savings in water usage.